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TITLE: TEST AND EVALUATION OF THE MAGNOGRAPH™ UNIT – A NONDESTRUCTIVE WIRE ROPE TESTER

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TECHNICAL NOTE

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METRIC CONVERSION FACTORS

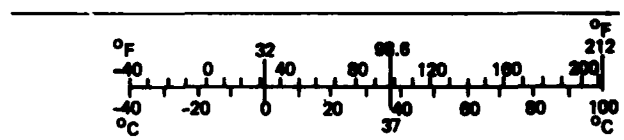
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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The nondestructive wire rope test device, a unitized AC/DC Magnograph, was tested for operational characteristics prior to acquisition by Naval field activities and start of inspection programs. The Magnograph was tested for loss of metallic area (LMA) and local fault (LF) detection accuracy. Wire ropes 1/2, 3/4, 1-1/8, 1-1/2, 2, and 2-1/2 inches in diameter were tested on a wire rope test track to find the accuracy of the unit. Two mining wire ropes, guy wires of a 1,000-ft-tall tower, and wire rope for 400-, 250-, and 30-ton cranes were used to determine operational characteristics of the Magnograph.

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CONTENTS

INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) previously conducted a study on nondestructive evaluation (NDE) equipment for wire rope inspection*, which compared conventional equipment (individual AC/DC units) to that of newly developed equipment (a unitized AC/DC unit, the Magnograph). The operational features of the two types of equipment were reviewed, and a limited test program was conducted to compare the results. The report recommended that the Magnograph equipment be purchased for Navy applications because it was found to be more versatile than the AC/DC units; e.g., data were recorded simultaneously on strip chart paper for both local fault (LF) defects and loss of metallic area (LMA) recordings and the equipment could be operated at slow speeds, to 0 fpm, and still detect LF and LMA data. This report presents results of a test and evaluation program conducted on the Magnograph unit before Navy field activities acquire the units and start field inspection programs.

Preliminary Testing With Broken Wire

The original two objectives of the program were: to define broken wire signals for producing a pictorial defect catalog and to determine the accuracy of the LMA data. The results would assist inspectors in interpreting data from field tests on wire rope. As testing progressed, it became clear that a defect catalog could not be developed. The LMA readings were found to be outside the manufacturer's accuracy specifications. A method for obtaining accurate LMA readings was developed, however, and is available to inspectors who take special effort to calibrate the equipment. The new calibration method is presented in this report.

The interpretation of LF data on broken wires requires experience to understand both gross and subtle meanings. Often signals of background noise are difficult to distinguish from signals of broken wires. The equipment sometimes does not give all the answers on broken wires; the data sometimes only indicates the general condition of the wire rope, especially if the wire rope is heavily worn or corroded. Some broken wires give signals that indicate definite breaks, but other broken wires give signals difficult to distinguish from background noise. In the latter case, broken wires can go undetected.

One of the more important findings of this program is that every broken wire does not produce an obvious broken wire signal.** Broken wires having a small gap between the broken ends produce only small

*Civil Engineering Laboratory. Technical Note N-1594: Nondestructive testing equipment for wire rope, by H. H. Haynes and L. D. Underbakke; Port Hueneme, Calif., Oct 1980.

**This finding also applies to the conventional DC-type equipment as well as to the Magnograph equipment.

defect signals which can be lost in the background noise. This limitation was first observed during a field test on an elevator wire rope taken from a mine and known to have a 1/8-inch gap. When the sensor head was moved slowly or rapidly over the broken wire, the break signal was totally lost in the background noise.

Further Tests

Consequently, a laboratory test track was built to accommodate a loop of wire rope 100 feet in length. Different sized wire ropes were tested that contained broken wires having various gap spacings. This work was planned for the defect catalog, but became an investigation of the minimum-sized gap which produces an observable break signal.

Field studies also indicated that used wire rope gave off considerably more background noise than new rope. It became apparent that a used wire rope would need to be taken apart to correlate the defect signals to the actual wire rope conditions. This work was done, and the results are presented in this report.

Magnograph Development

The Magnograph unit has only recently become available for purchase from the manufacturer (Heath and Sherwood Limited, Ontario, Canada). The manufacturer's discussion on engineering principles and operation of the equipment is presented in the Appendix (the manufacturer's operation manual).

It is important to mention that as limitations of this new equipment arise, the developers (Noranda Research Centre, Montreal, Canada) and Heath and Sherwood work to solve the problems. For example, during the NCEL tests it was observed that the LMA recordings were drifting with time. Part of the problem was an electronic component failure, but another part was the temperature sensitivity of the Hall sensors. Both developer and manufacturer solved the problem and have upgraded subsequent equipment.* Noranda has improved the calibration method for LMA readings. Thus, the equipment is evolving and improving as problems are noted and solved.

TESTING

Scope

New wire ropes of 6x25 right-regular-lay, fiber-core construction, having diameters of 1/2, 3/4, 1-1/8, 1-1/2, 2, and 2-1/2 inches, were tested with manmade broken wires. The broken wires had gap spacings that varied from 0 to 1/2 inch in 1/16-inch increments. A used wire rope of 6x31 regular-right-lay, fiber-core construction, having a 1-1/8-inch diameter, was tested and disassembled to compare LF signals with the actual condition of the wire rope. Other tests investigated signal size as a function of gap configuration, orientation, and rope speed.

*NCEL's equipment has not been upgraded with this feature.

LMA accuracy was determined by adding individual wires to a wire rope so that the known actual change in percent LMA could be compared to the recorded change in percent LMA.

Test Setup

A test track (Figure 1), designed to accommodate a 100-foot loop of wire rope, was constructed to conduct tests on running wire ropes of various diameters and constructions. Wire rope speed was infinitely variable by means of a variable speed transmission powered by a 1-3/4-hp electric motor. Rope speeds are variable from 0 to over 800 fpm.

Each end support consists of three 1-foot-diameter sheaves that simulate a 4-foot-diameter sheave. The larger sheave diameter was needed to supply the larger wire ropes with an acceptable bend radius.

DISCUSSION

Gap Configuration

A broken wire can have various shaped ends that produce gaps of different configurations. A fatigue break gives square ends, while a tensile break causes the ends to neckdown. Another condition occurs when a wire is bent and pushed to the side (Figure 2d). A series of tests was conducted on different gap configurations (Figure 2) to determine the effective gap size. The results indicated that the signal size depended on the clear air gap size in the longitudinal direction. Hence, wires that are pushed sideways and are grossly displaced produce a signal size that is dependent mainly on the longitudinal gap size.

Gap Orientation

Gap orientation refers to the location of a wire break in relation to the four Hall-effect devices that were located 90 degrees apart in the sensor head. In these tests a wire break could be directly under a Hall-effect device, while at other times a break could be oriented up to 45 degrees from the device.

The test to determine the effect of gap orientation used a 1-1/2-inch-diameter wire rope with two manmade wire breaks approximately 4 yards apart (A and B of Figure 2). Break A was a broken crown wire, and Break B was a broken filler wire. On the test stand, a break appeared at the same orientation after each complete loop. Hence, for this test the sensor head was rotated from 0 through 90 degrees in 22.5-degree increments. The LF data were compared to observe any changes in the signal size.

Figure 3 shows that the signal size changed considerably: between the maximum and minimum signal, a 40% decrease for each wire break signal was noted. The test was not designed to determine the orientation of the break in relation to the Hall-effect devices; however, the data from break A revealed that for the minimum signal size, the probable break orientation was 45 degrees from a Hall-effect sensor because the signal size changed only once for the five readings. Surprisingly, the data from break B changed signal size for each orientation. Regardless of the differences between breaks A and B, the signal size was dependent on gap orientation.

Gap Space

New Rope. A series of tests was conducted on new wire rope to determine LF signal size as a function of longitudinal gap space. A hammer and chisel were used to make wire breaks in crown wires. The initial gap space was about 1/128 inch, but a file was subsequently used to widen the gap spacings to 1/2 inch in 1/16-inch increments.

Tests were conducted on wire rope 1/2, 3/4, 1-1/8, 1-1/2, 2, and 2-1/2 inches in diameter. Rope speed was 200 ft/min in all cases, except for the 2-1/2-inch-diameter wire rope. For that rope, the sensor head was pulled over the wire rope because the drive wheel of the test stand could not develop sufficient traction to maintain movement of the rope.

A condensation of the data for the various tests is shown in Figures 4 through 9. From these data, LF signal-to-noise ratios were obtained for each gap space. The background noise was defined as an average of the peak values for each rope.

Figures 10 through 15 show LF signal-to-noise ratio as a function of gap space. Interestingly, the LF signal-to-noise ratios ranged from 2 to 4 for a gap space of about zero. Therefore, one would expect to easily detect a broken wire even when the gap space is extremely small, but this is not necessarily true because of two conditions: (1) the above data were collected on new wire rope, and (2) the background noise was the average of the peak values.

New wire rope is fairly clean of background noise; once surface corrosion occurs, however, background noise increases. As a wire rope is worked, the strands and wires seat themselves relative to one another. Internal and external wear, along with peening and nicking, is another cause for background noise. Heath and Sherwood propose to track the growth of background noise as an indication of the condition of the wire rope (see the Appendix). Data on the growth of background noise are not available, but it is expected that LF signals for small gap sizes would quickly be lost in the background noise.

The other condition -- that of using average peak values for background noise -- means that above-average background-noise signals can appear to be LF signals. Many times, confusion exists when studying a signal as to whether it is an LF or a background noise signal. This occurs most frequently in heavily used wire ropes.

In summary, LF signal size is dependent on the gap space, and broken wires with extremely fine gap spacings can be detected in new wire rope.

Used Rope. The difficulty of distinguishing between LF signals from small gap spacings and background noise was investigated by nondestructive testing and then by disassembling a used wire rope. A 1-1/8-inch-diameter, 6x31 fiber-core wire rope, which had been retired from a mine elevator hoist, was used in the test. A 100-foot-long section was mounted on the test stand. Magnograph data were obtained at a rope speed of 200 ft/min; raw data are shown in Figure 16. Several large LF signals indicate broken wires, but the intermediate-sized LF signals take more experience to define.

The first 36 feet of the rope were disassembled for a detailed study. Three crown wire breaks and five filler wire breaks were found (see Figure 17). As can be seen, several filler wire break signals were the same size as the background-noise signals. It appears that inexperienced inspectors would have a difficult task distinguishing between these types of signals.

Rope Speed

The Hall-effect devices, which detect broken wires by picking up a magnetic flux leakage field created by a discontinuity in the wire rope, are not dependent on rope speed to generate a signal.* It has been demonstrated that the Magnograph unit detected broken wires when the sensor head was moved slowly over breaks on wires. The LF signal remained even when the sensor head was at a standstill over the broken wire. However, it was noted during field tests that the LF signal size varied to a limited degree with rope speed, which led to further investigation.

A test was conducted on a 1-1/8-inch-diameter, 6x25 regular-right-lay, fiber-core rope to observe the effect of rope speed on LF signal size; break gap spacing was about 1/8 inch. Figure 18 shows that as the rope speed changed from 50 to 800 ft/min, the signal-to-noise ratio ranged from a maximum of 7 to a minimum of 2. As the rope speed increased, the background noise became larger, so the signal-to-noise ratio decreased. The manufacturer recommends testing at rope speeds of 50 to 600 ft/min, which is acceptable, but higher rope speeds are also acceptable.

Rope Guides

The Magnograph unit's sensor head can be used for wire ropes with diameters varying from 1/2 to 2-1/2 inches by using different-sized rope guides and adaptor tubes. The equipment uses five different rope guides to accommodate all wire rope diameters (see Appendix, Figure 4.3): four adaptor tubes handle ropes from 1/2 to 2 inches in diameter, and the larger rope diameters of 2 to 2-1/2 inches are handled without an adaptor tube.

Tight and loose fit were investigated for the effect on LF signal-to-noise ratio of a rope traveling through the sensor head. The manufacturer recommends rope guide C for wire ropes of 1-1/8 to 1-9/16 inches in diameter, and rope guide D for 1-9/16 to 2 inches in diameter. The 1-1/2-inch-diameter wire rope used in the test had a tight fit in rope guide C, but a loose fit in rope guide D. The LF signal-to-noise ratio for rope guide C was about 10 and for rope guide D about 6. When going from the tight to loose fit, the LF signal size decreased slightly and the background noise increased substantially. Consequently, the rope guide with a tight fit is recommended.

*Conventional DC-type wire rope t sters ar dependent on rope speed to generate a signal.

Accuracy of LMA

NCEL's Magnograph equipment was modified by Noranda during FY81 to simplify the calibration procedure for determining LMA. The original equipment used a calibration procedure that required knowing the mass per unit length of the wire rope. Many times this value had to be estimated, generating a source of error. The Noranda modification entailed some circuitry revision along with a new calibration curve. The new method eliminated the need for prior knowledge of the mass per unit length of the wire rope.

The accuracy of the LMA readings decreased with this modification. Tests to determine the accuracy were conducted on wire ropes of 1-1/8- and 2-inch diameter, 6x25 right-regular-lay, fiber-core construction. Extra wires (about 15 feet) were added to the wire rope by taping them into the valleys between the strands to simulate an increase of mass. Figure 19 shows that significant differences exist between the known change in LMA and the Magnograph readings. Revisions in the calibration curve would make some improvement in the accuracy, but that procedure by itself is not enough to improve the accuracy to meet the manufacturer's specifications.

Noranda has recently developed a self-calibrating system that does not require a calibration curve. The sensor head determines the mass of the rope by measuring the flux flow through the rope. A given voltage change (1 volt) from the zero condition represents a 10% loss or gain in metallic area. NCEL has tested this system, and its accuracy is ±0.05%. This self-calibrating system will probably be used for all future equipment.

NCEL's Magnograph equipment can be manually calibrated to simulate the self-calibrating process as described in the Appendix. The procedure is to start the calibration process before the sensor head is placed on the wire rope. In the self-calibrating procedure the following steps should be taken by the operator:

1. With a four-digit read-out Volt-Ohm-Milliamp (VOM) meter, plug the test leads into the LMA input receptacles of the Magnograph chart recorder.

2. Turn on the recorder and electronic sections.

3. On the electronic section, adjust the LMA <u>zero</u> potentiometer until 0 volt is obtained (have the VOM on the 2-volt scale).

4. Now place the sensor head on the wire rope and adjust the LMA <u>gain</u> potentiometer until +1.000 volt is obtained on the VOM.

5. Then go back to the LMA <u>zero</u> potentiometer and adjust until 0 volt is obtained.

By using this new method to calibrate the Magnograph unit, LMA accuracy is well within the ±0.5% accuracy by area specified by the manufacturer.

LMA for 30% Crown Wire Wear

The Magnograph equipment measures total LMA that results from wear and corrosion. Navy inspection criteria specify that a wire rope with 30% or more reduction in the diameter of the crown wires must be removed from service. The question posed is: what is the approximate LMA for 30% crown wire wear?

The crown wires of three different wire rope samples (1/2-, 1-1/8-, and 2-inch-diameter 6x25 right-regular-lay, fiber core) were abraded on a belt sander to simulate various degrees of wear. Physical samples had to be used because, for different degrees of wear, the number of crown wires showing wear at any given cross section varied. For example, for 5% crown wire diameter reduction, only one crown wire per strand showed wear; but for 30% crown wire diameter reduction, three crown wires showed wear. Using these data, calculations were made of LMA and are shown in Figure 20. It can be seen that for 30% crown wire diameter reduction, the LMA percentages were about 5.5, 4.0, and 2.0 for wire ropes of 1/2-, 1-1/8-, and 2-inch diameter, respectively.

To an inspector, significant wear is easily detected. The appearance of a wire rope with 30% crown wire diameter reduction is visibly startling in its impact because of the "used" or "poor" condition of the rope. Figure 21 is an example of a wire rope with 12% crown wire reduction and one broken wire. It is doubtful that many wire ropes stay in service until crown wire wear is 30%, solely because of the poor appearance of the rope.

Canadian mining practices require nondestructive evaluation of wire ropes and a 10% LMA is cause for removal of a wire rope from service. To reach 10% LMA, it is apparent that the effect of corrosion has to be more significant than that of wear. Assuming a rope of 1-1/8-inch-diameter, one can determine that reasonable wear can be about 2% LMA; therefore, corrosion would make up the other 8%. Corrosion is more insidious than wear because it can be hidden from view, and corrosion pitting causes stress risers in the wires. Wear is an easy condition to inspect for, but corrosion is a more significant cause for wire rope failures. The Magnograph equipment is an important tool in determining the degree of corrosion in wire ropes.

FINDINGS

1. The air gap between ends of a broken wire, as measured in the longitudinal direction of the wire rope, is the predominant factor governing LF signal size.

2. The orientation of a broken wire with respect to the four Hall-effect devices in the sensor head also influences the LF signal size.

3. Broken wires having a gap of less than 1/32 inch can be detected in new wire ropes, but with used rope the background noise is greater and can obscure the LF signal. Hence, not all broken wires can be detected by the Magnograph equipment.

4. LF signal size is very slightly influenced by rope speed (Figure 18).

5. A wire rope guide that provides "a best fit" on a rope should be used; a tight fit is better than a loose fit.

6. The accuracy of LMA readings for the Magnograph unit is outside the manufacturer's specifications; however, a new method has been developed by the manufacturer to improve the accuracy. New equipment will have a self-calibrating capability; NCEL's equipment can be manually calibrated. This method brings the LMA readings well within the manufacturer's specifications.

CONCLUSIONS

1. Broken wires with a small gap between the ends do not always produce an LF signal of sufficient size to be distinguished from background-noise signals.

2. At the present time, the Magnograph unit should be used as an inspection tool to augment the inspector's skills. It is valuable because the internal condition of wire ropes, particularly broken wires and corrosion, can be detected.

3. The Magnograph equipment provides considerably more technical data on the rope's condition than is available by using visual inspection and will indicate areas that require further inspection.

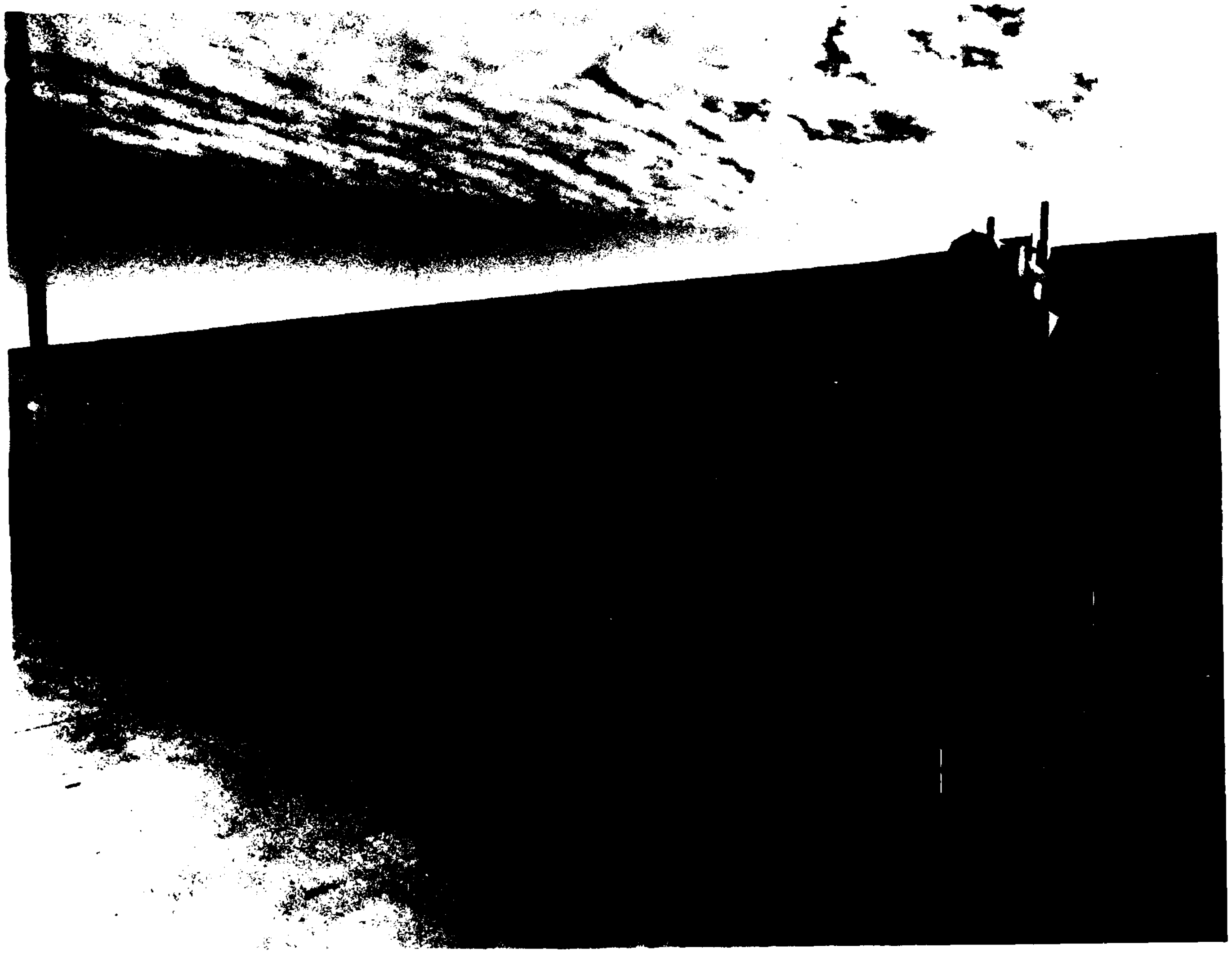
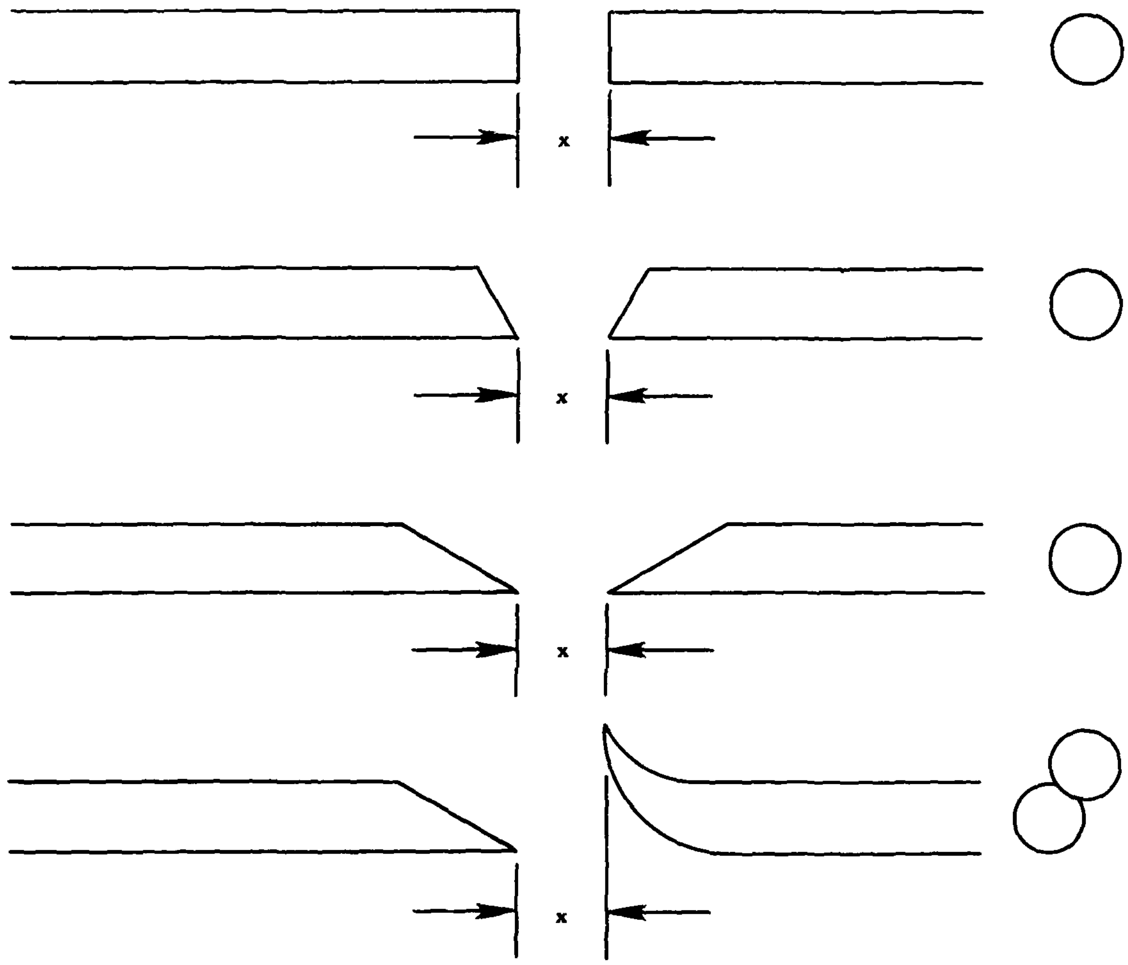


Figure 1. Test stand for wire ropes.



x = clear air gap space in longitudinal direction of wire rope

Figure 2. Gap configurations for wire rope.

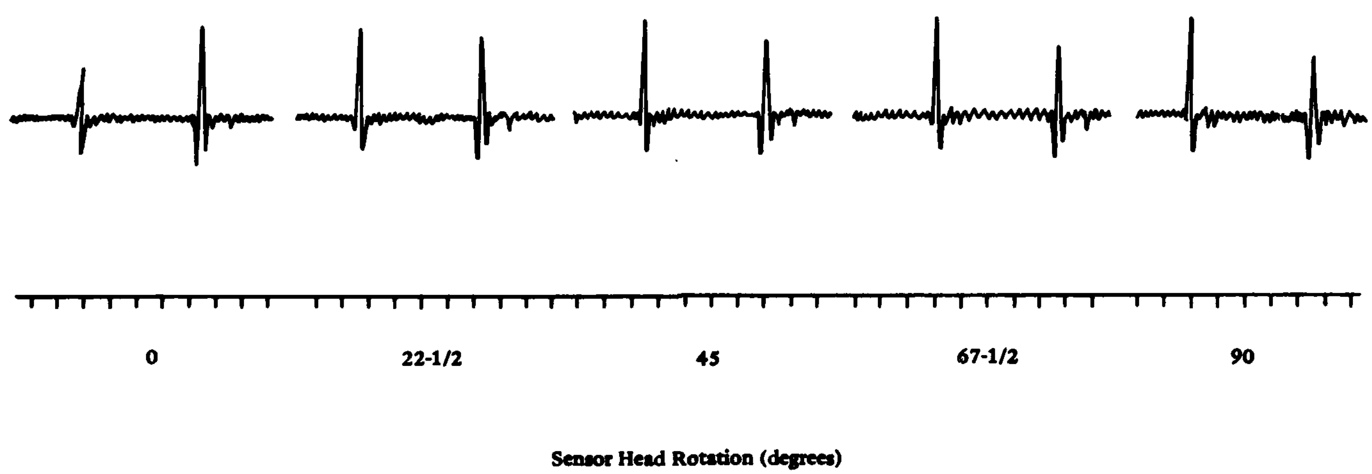


Figure 3. Sensor head rotated about 1-1/2-in.-diam wire rope to determine signal size as a function of gap orientation.

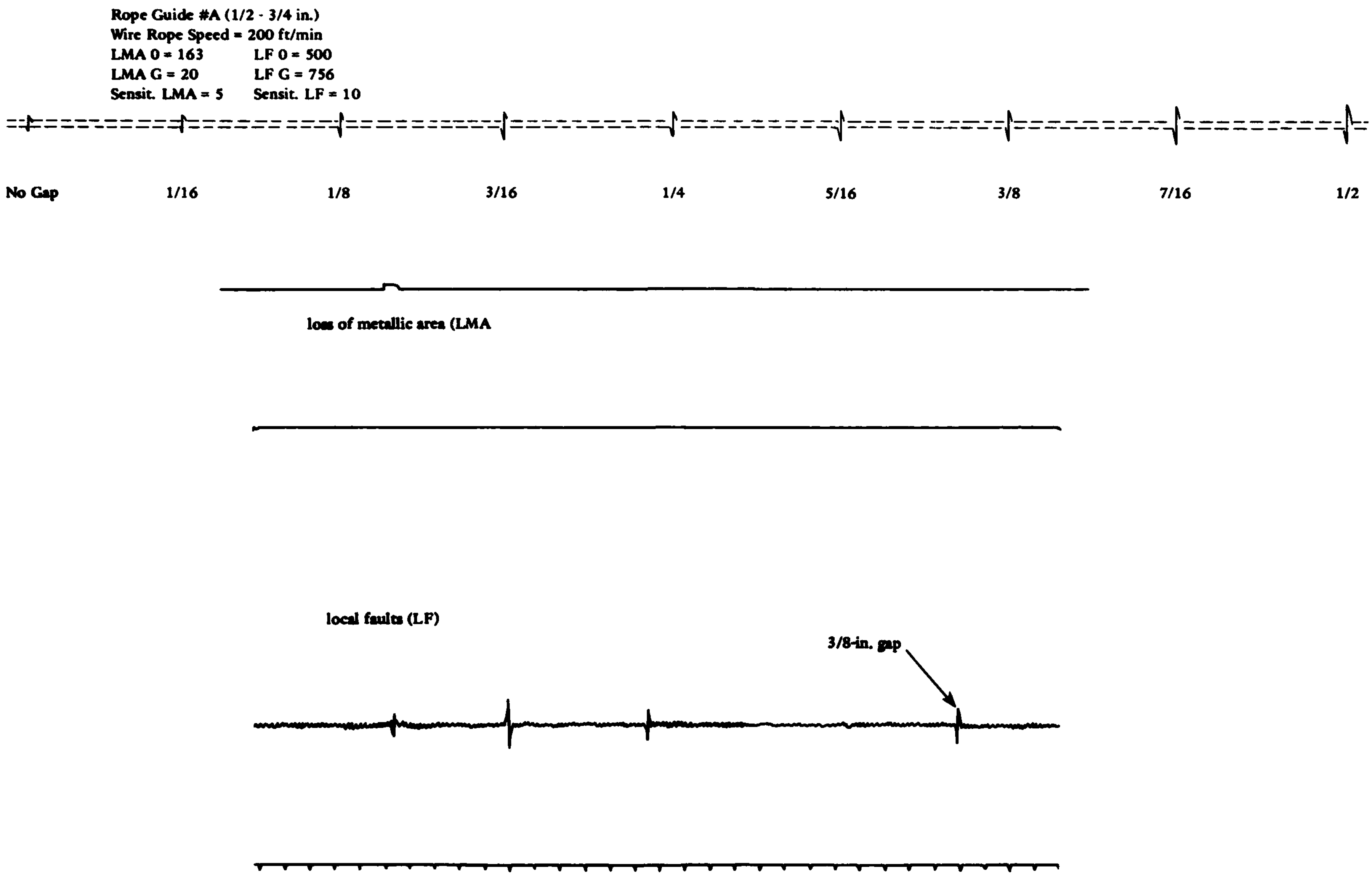


Figure 4. LF signal size as a function of gap spacing for 1-1/2-in.-diam wire rope.

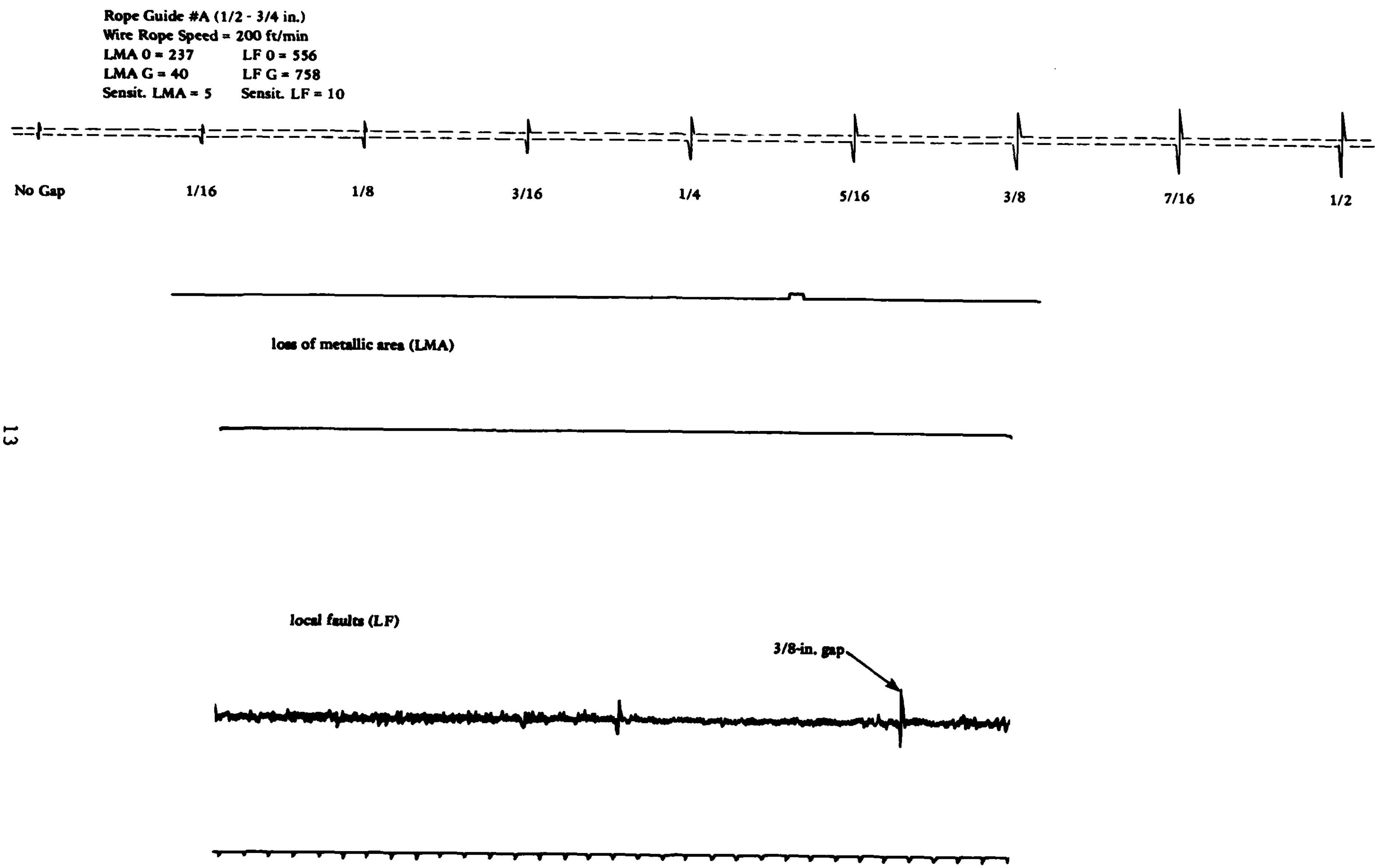


Figure 5. LF signal size as a function of gap spacing for 3/4-in.-diam wire rope.

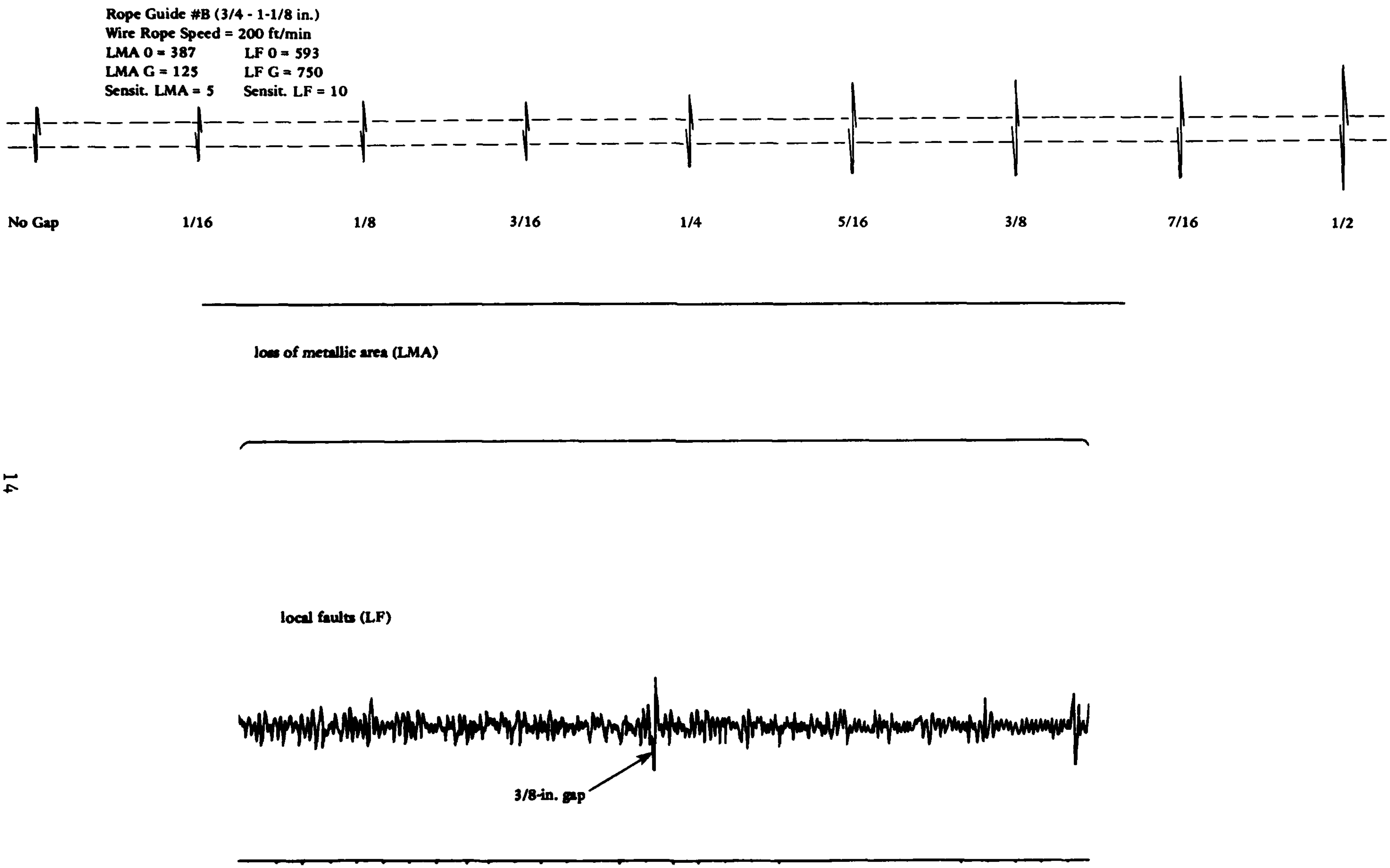


Figure 6. LF signal size as a function of gap spacing for 1-1/8-in.-diam wire rope.

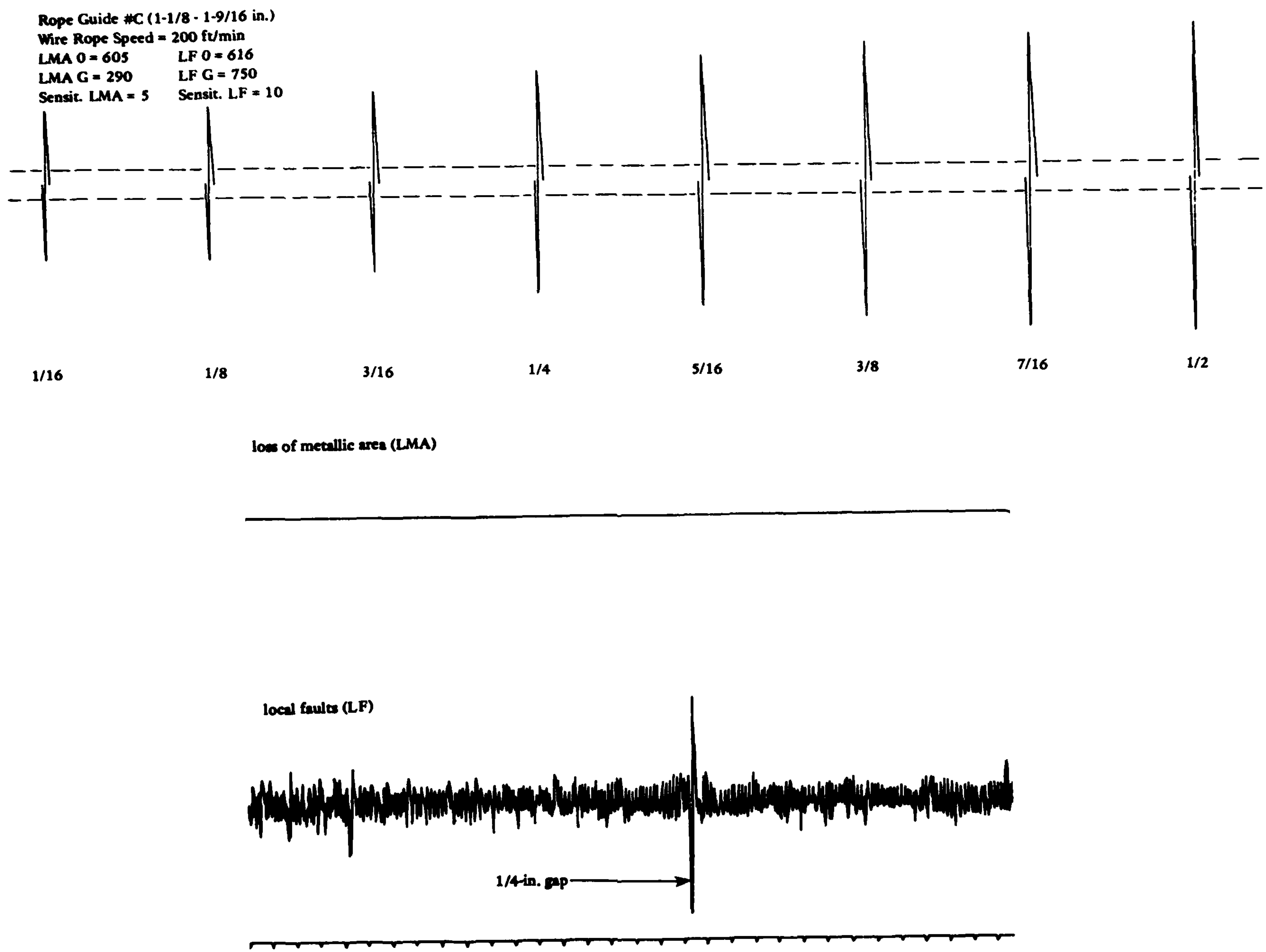


Figure 7. LF signal size as a function of gap spacing for 1-1/2-in.-diam wire rope.

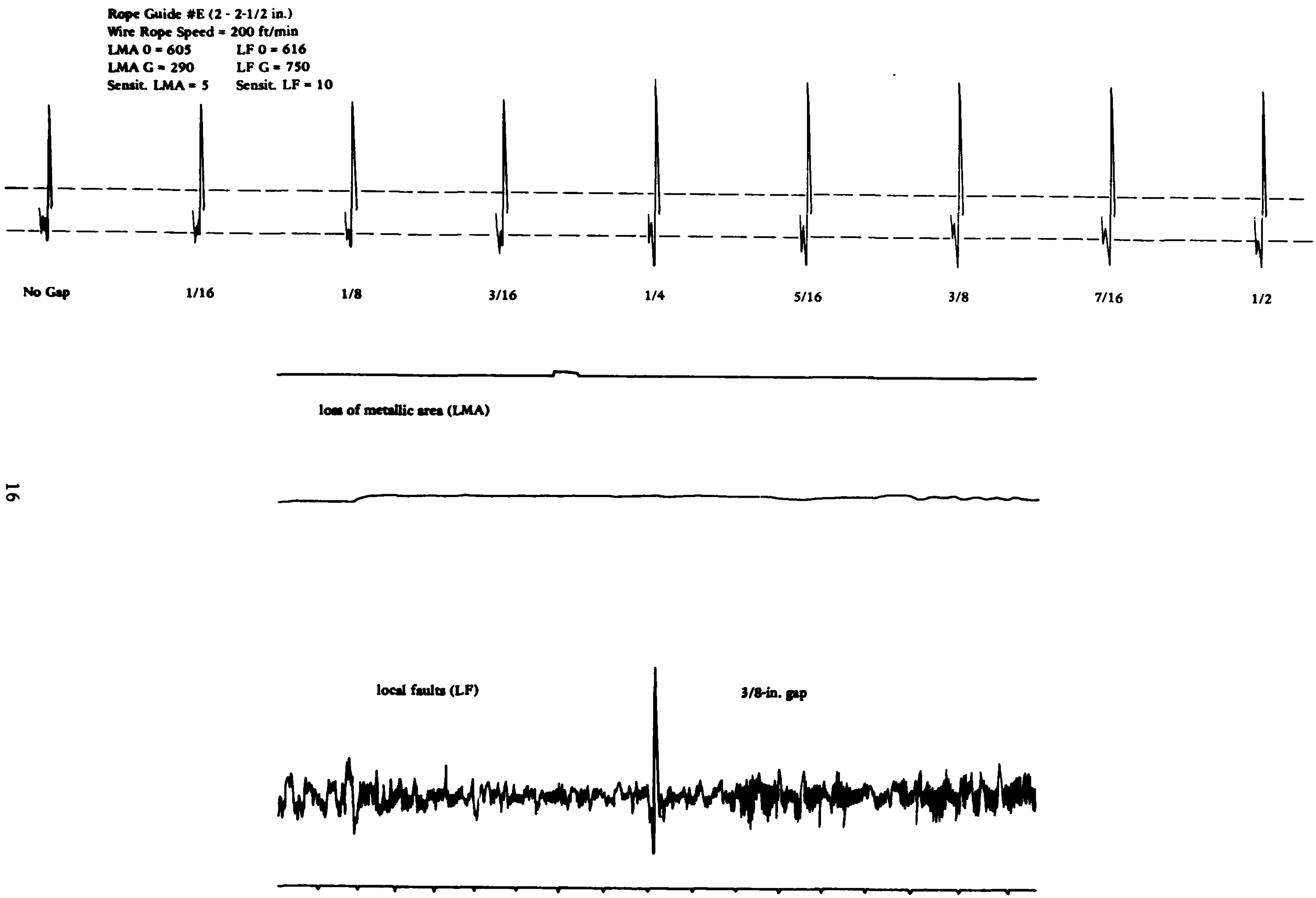


Figure 8. LF signal size as a function of gap spacing for 2-in.-diam wire rope.

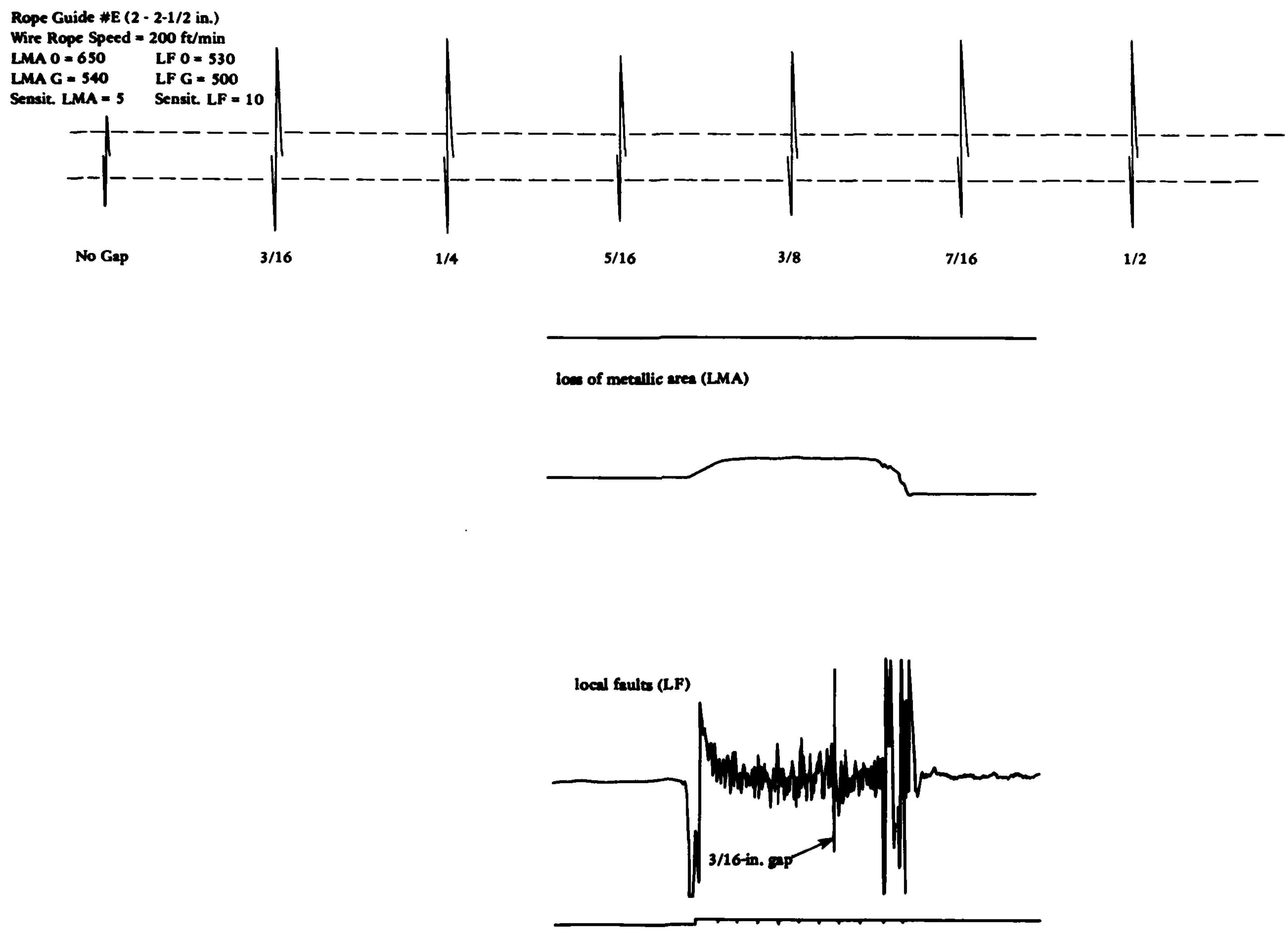


Figure 9. LF signal size as a function of gap spacing for 2-1/2-in.-diam wire rope.

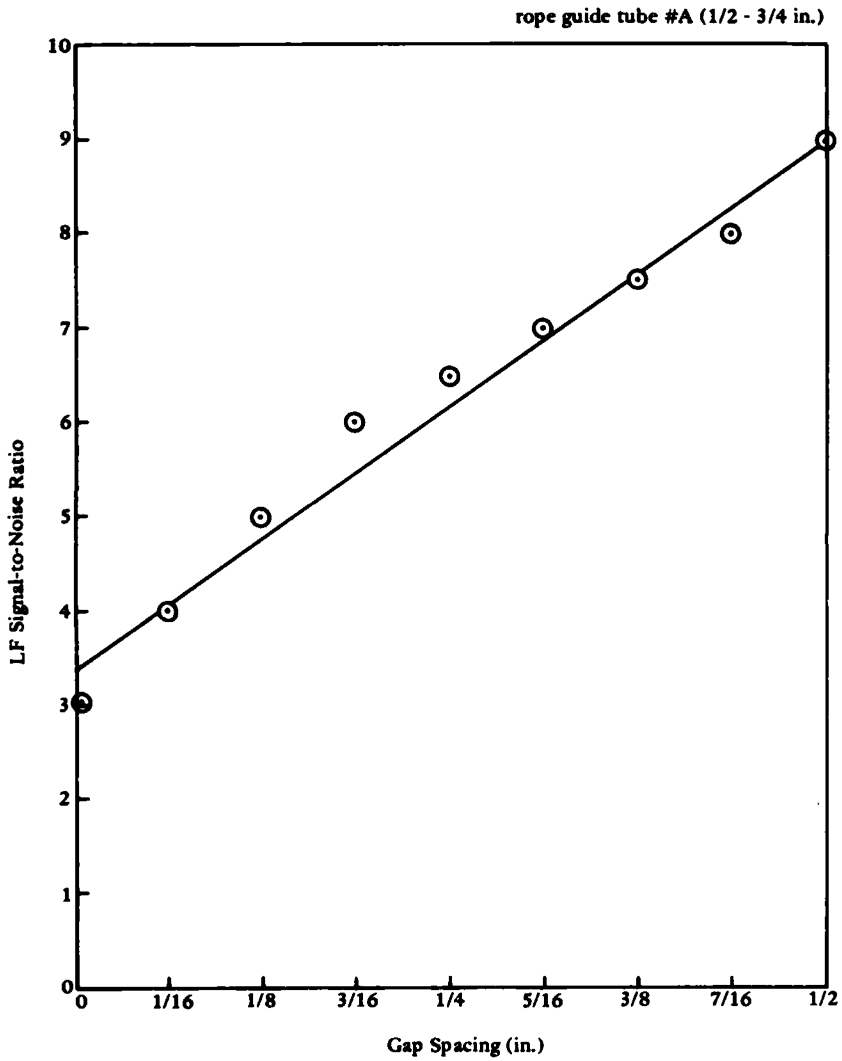


Figure 10. LF signal-to-noise ratio as a function of gap spacing for 1/2-in.-diam wire rope.

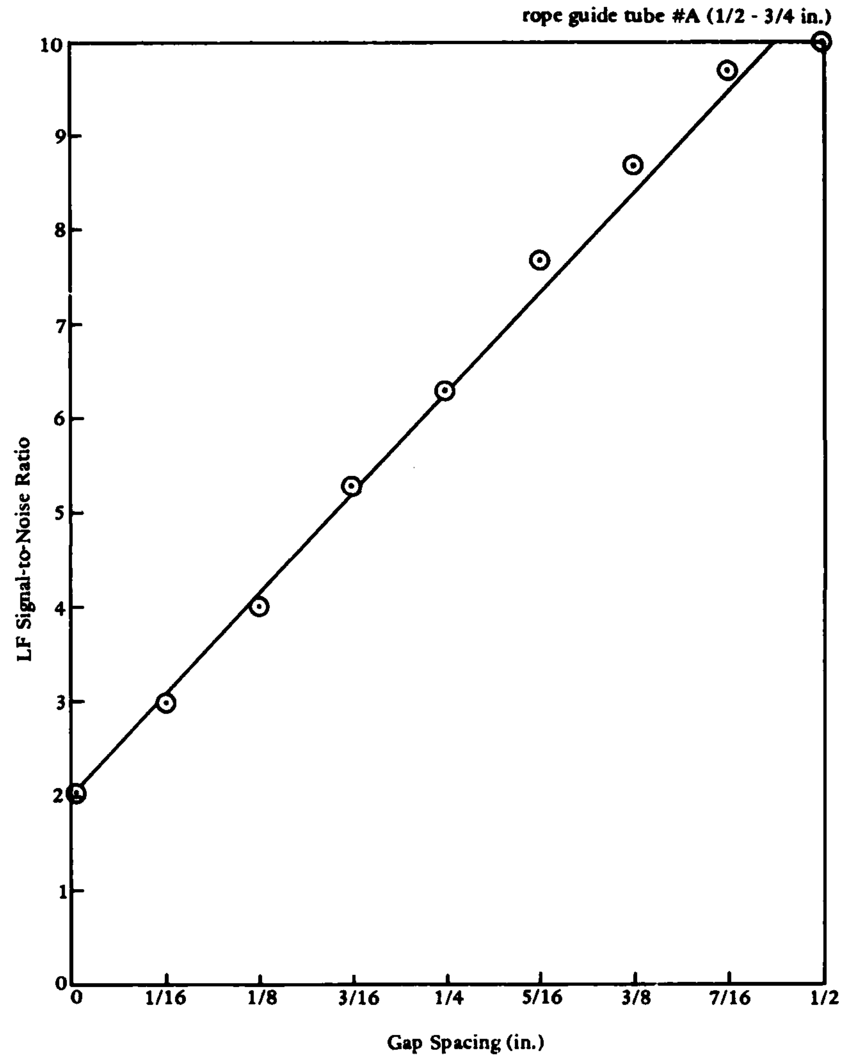


Figure 11. LF signal-to-noise ratio as a function of gap spacing for 3/4-in.-diam wire rope.

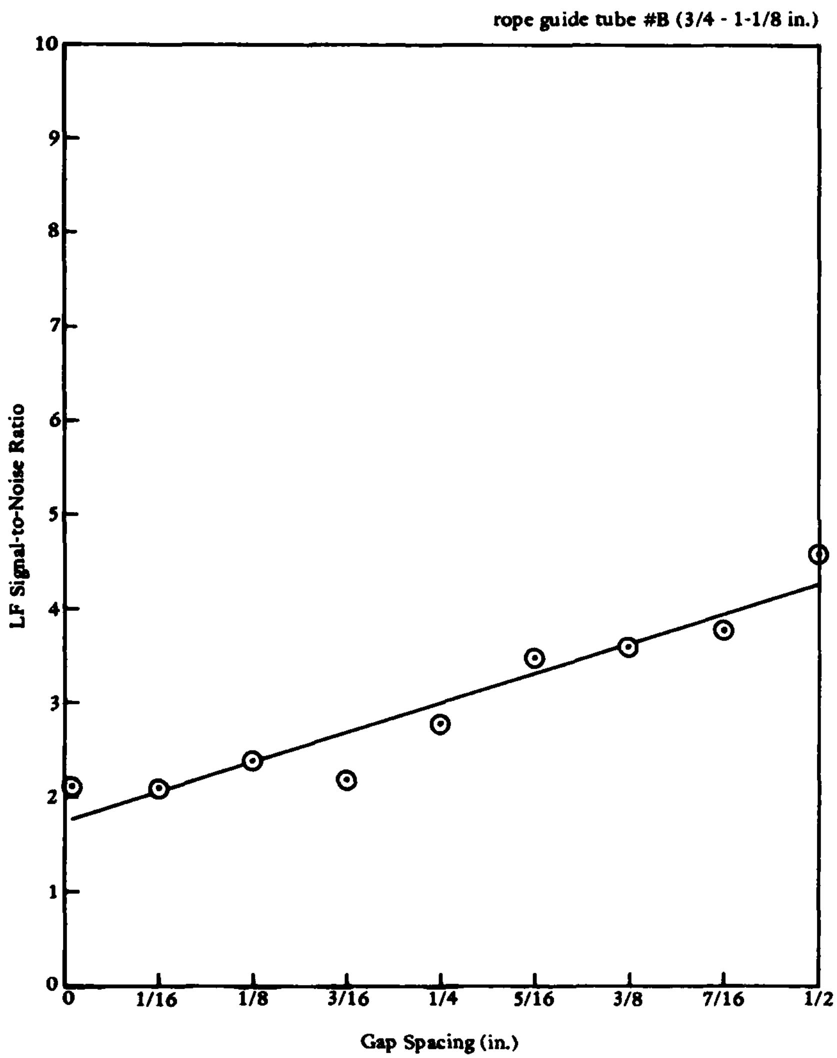


Figure 12. LF signal-to-noise ratio as a function of gap spacing for 1-1/8-in.-diam wire rope.

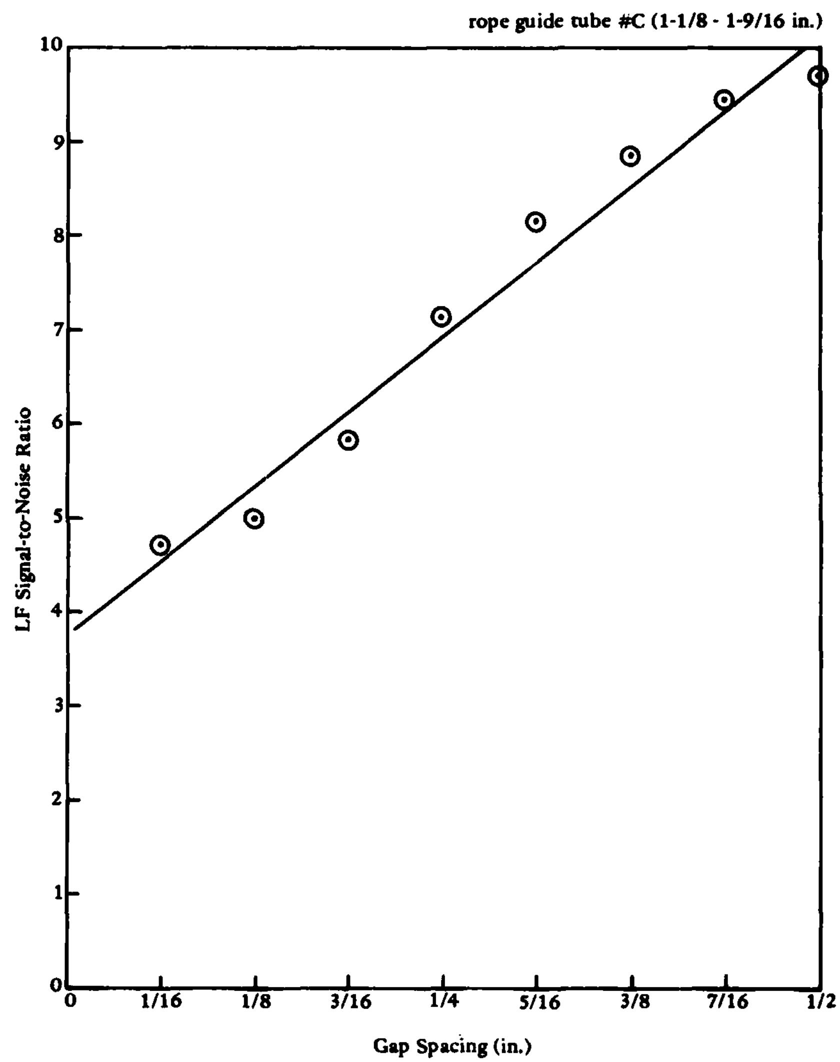


Figure 13. LF signal-to-noise ratio as a function of gap spacing for 1-1/2-in.-diam wire rope.

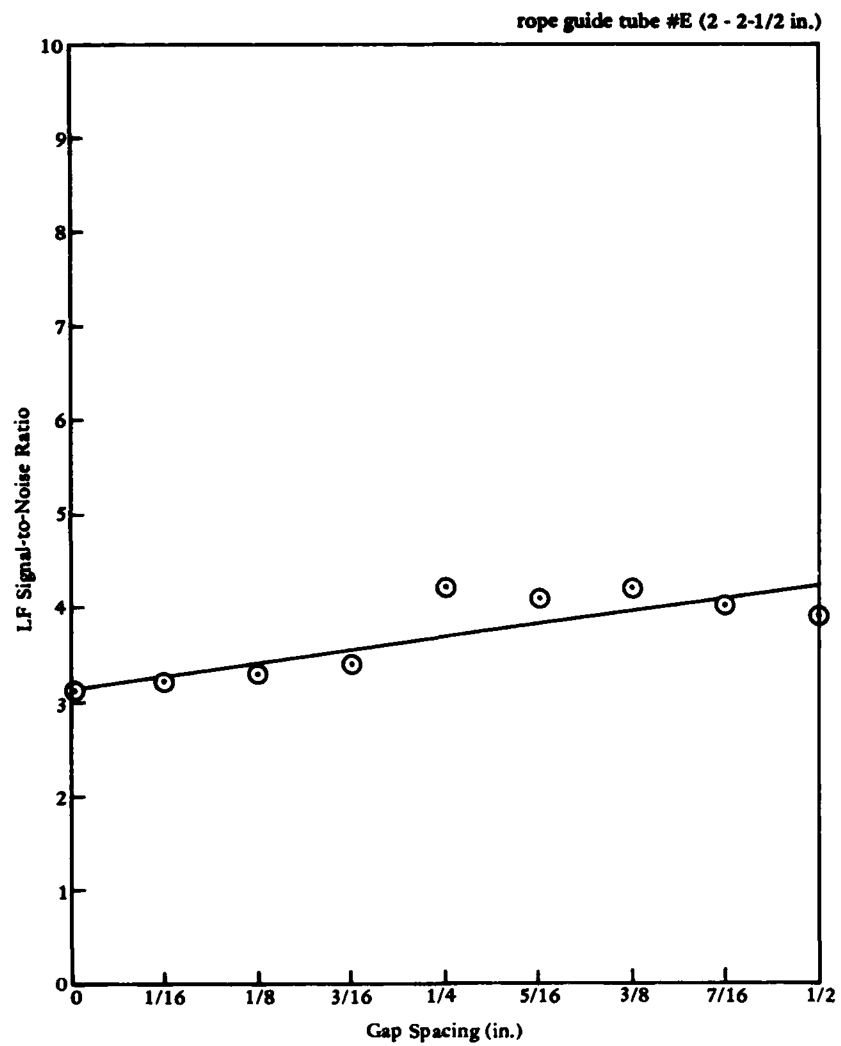


Figure 14. LF signal-to-noise ratio as a function of gap spacing for 1-in.-diam wire rope.

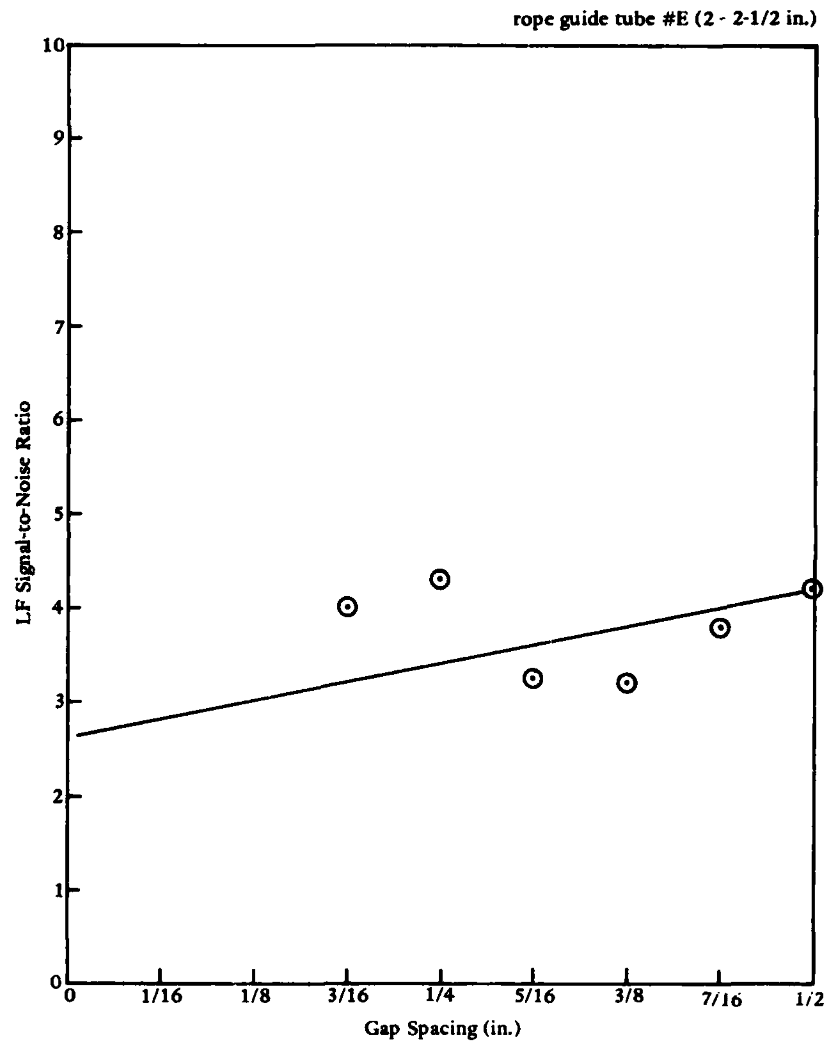


Figure 15. LF signal-to-noise ratio as a function of gap spacing for 2-1/2-in.-diam wire rope.

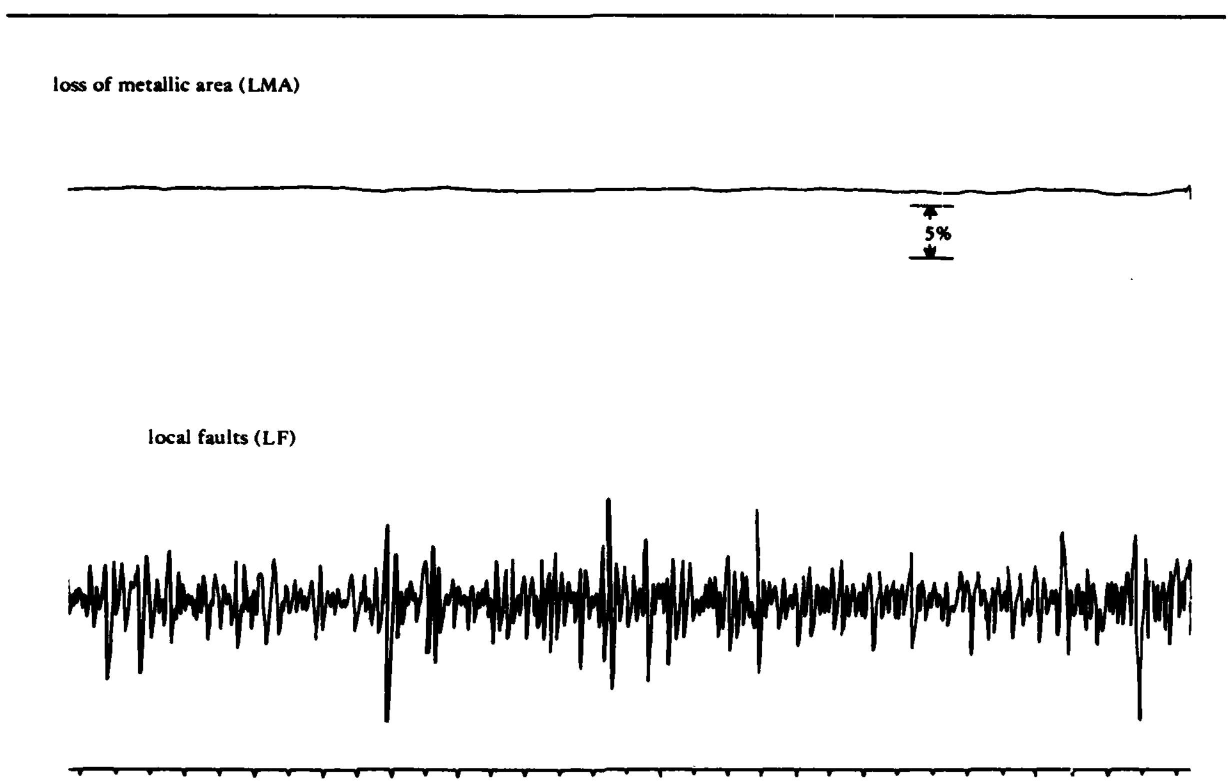


Figure 16. Raw data from a used mine elevator hoist rope.

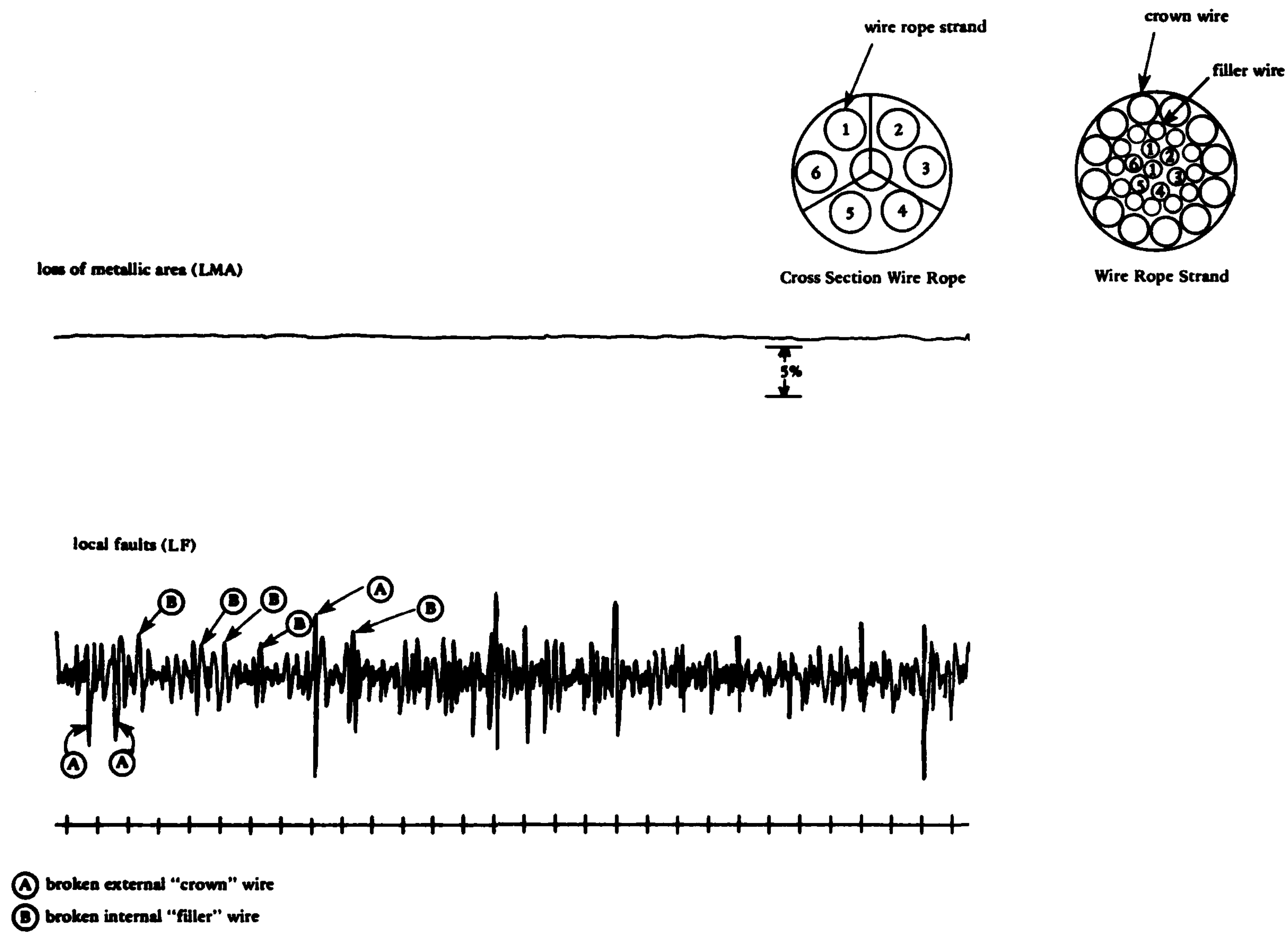


Figure 17. LF signal chart of used mine elevator hoist rope with broken wires found when taken apart.

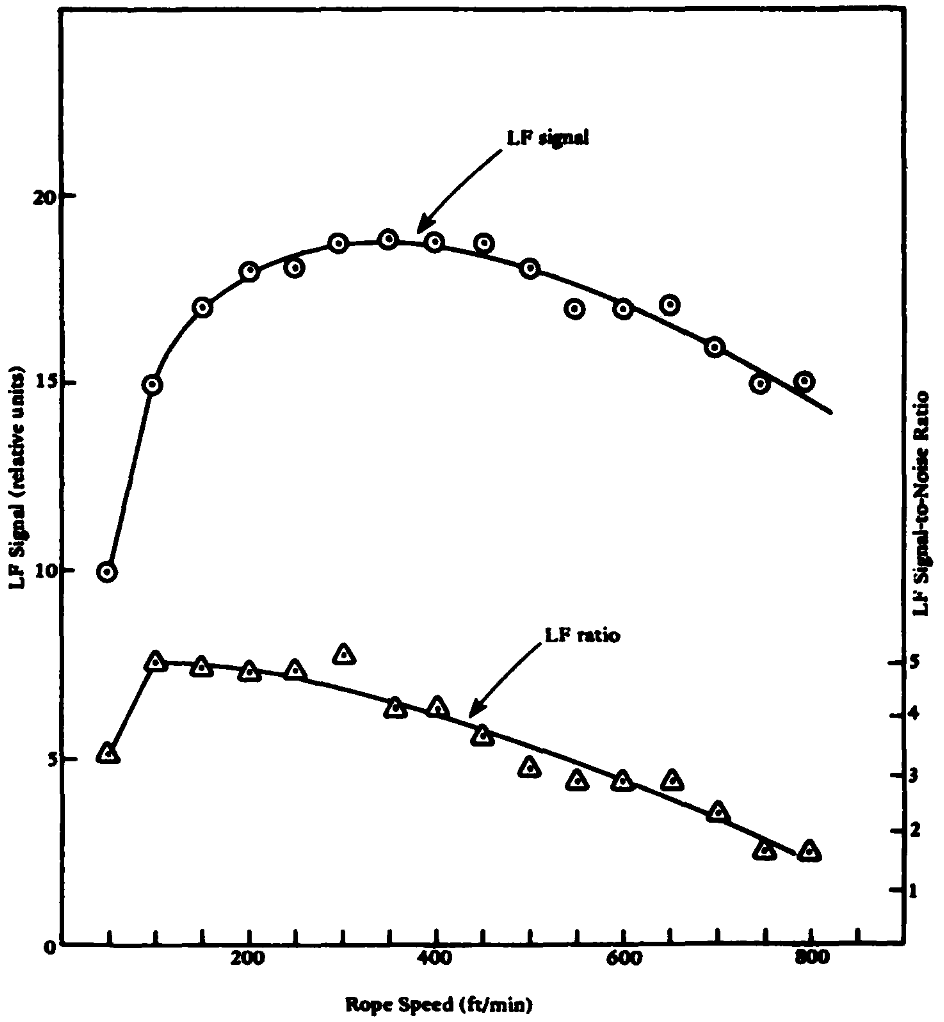


Figure 18. LF signal size as a function of rope speed for new 1-1/2-in.-diam wire rope.

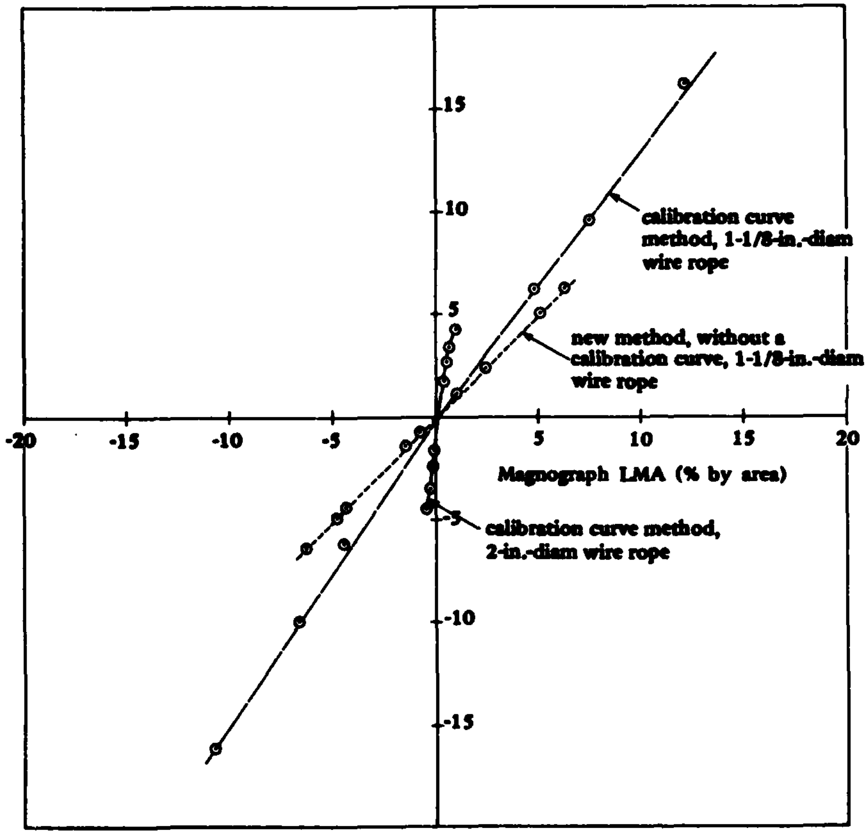


Figure 19. Tests for accuracy of LMA readings.

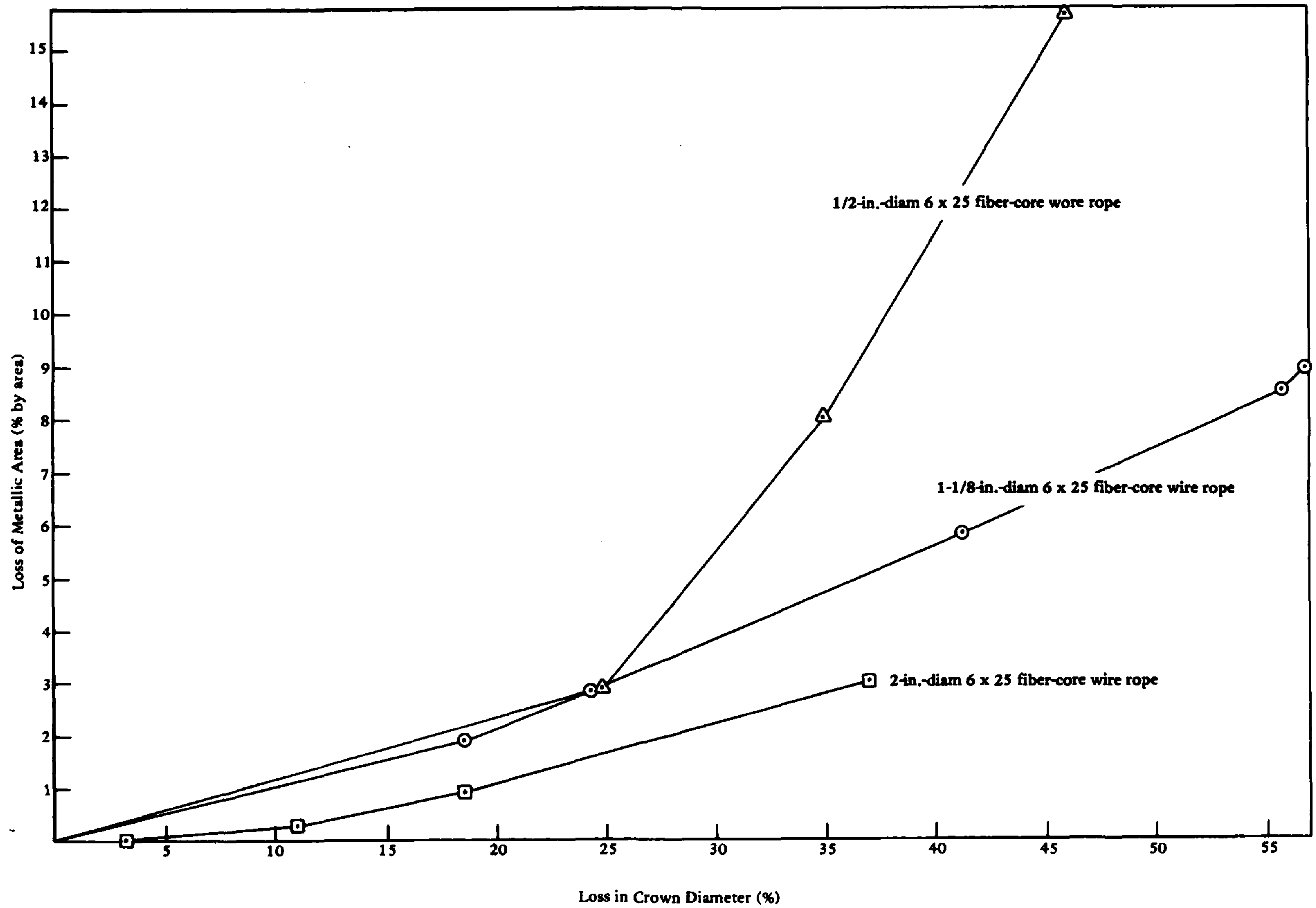


Figure 20. LMA as a function of crown wire wear.

Figure 21. Wire rope 1-1/2-inch in diameter with 12% crown wire wear.

Appendix

MANUFACTURER'S OPERATING AND MAINTENANCE MANUAL FOR MAGNOGRAPH MODEL MAG-1

This appendix presents a method for nondestructive testing of wire rope as proposed by Heath and Sherwood in April 1981.

1.0 General Information

The MAGNOGRAPH™ non-destructive wire rope tester uses Hall Effect Sensors and a strong static magnetic field to measure wear and breakdown of wire ropes. It will test ropes of any construction from 1/2 to 2 1/2 inches (12-64mm) in diameter at speeds from 0 to 600 ft./min. (0-3 m./s.)

The instrument gives simultaneous readings of a rope's metallic cross-sectional area and of localized faults such as broken wires, wire ends, wire nicks and corrosion.

The Magnograph consists of three major parts:

1) The Sensing Head - through which the rope is passed and which does the basic detection of the fault.

2) The Electronic Control Section - which processes the Sensor Head signals and records the test on magnetic tape.

3) The Recorder Section - which provides a strip chart visual representation of the rope test.

The complete Magnograph instrument, model Mag-1, is shown in Fig. 1.0.

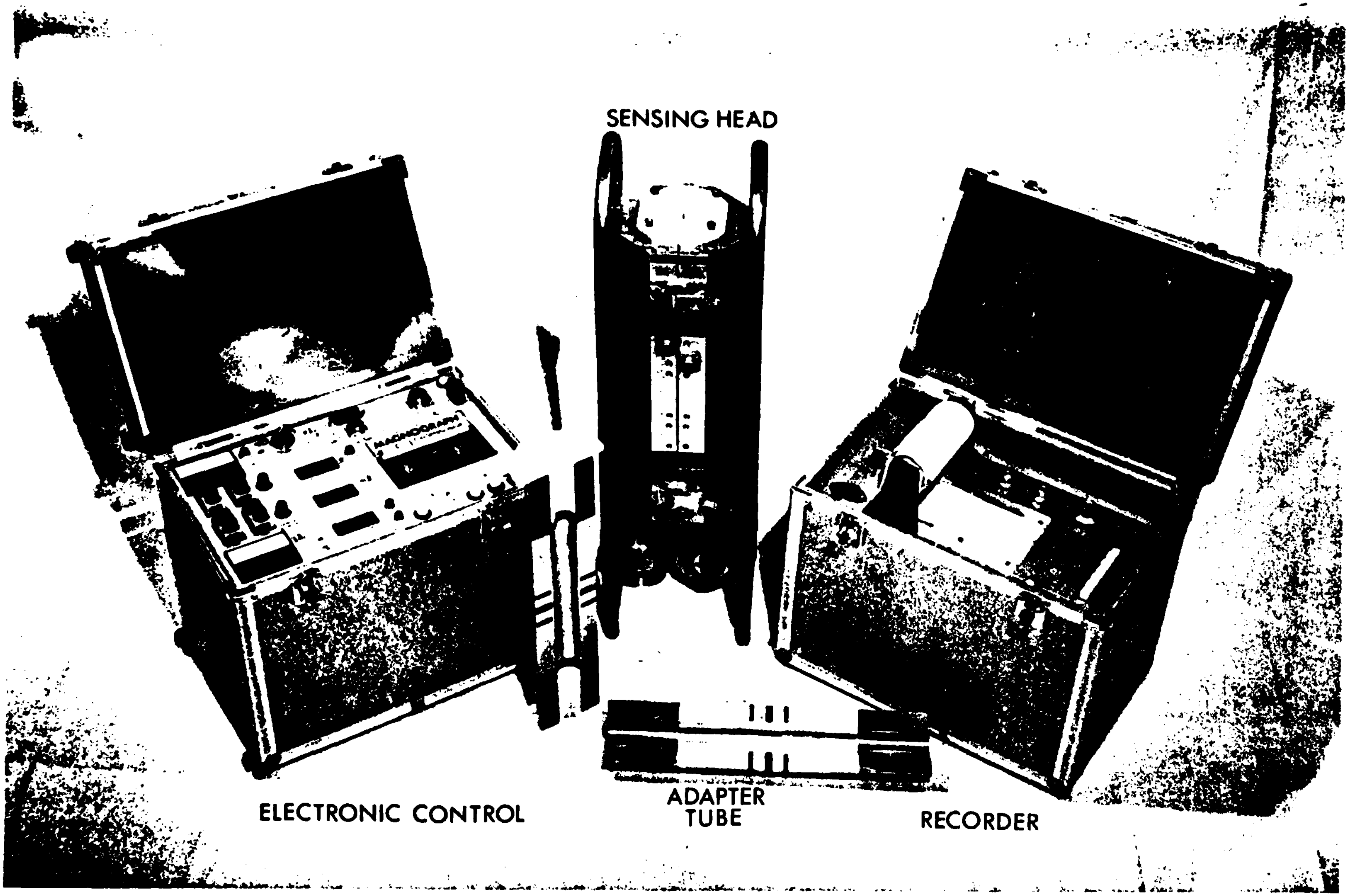


Fig. 1.0 Magnograph Non-Destructive Rope Tester

2.0 Specifications

The specifications listed below apply to Sensor Head and Electronic Control Sections of this instrument when operated and maintained as per this manual. These specifications are subject to change without notice.

Specifications other than weight for the Chart Recorder can be found in Gould manual No. 15-806325-00.

2.1 Electrical

Power Requirements -
Line Operation of Electronic Control Section and Battery Charging

115VAC $\pm$ 10%, 50/60Hz	40	VA	switch selectable
230VAC $\pm$ 10%, 50/60Hz	40	VA	

Operation by external battery of 11.5-14VDC on Control Section only. (Current consumption is approximately 2 amps) Internal Nicad battery in Control Section will provide 8 hrs of continuous operation when fully charged.

2.2 Mechanical

Weight (lbs)		Dimensions (ins.)
Sensor Head -	105	28Hx8Lx8D
Electronic Control -	45	15Hx17Lx11D
Chart Recorder -	35	15Hx17Lx11D

2.3 Environmental

Operating and Charging

Sensor Head - 20^{o}c to + 40^{o}c

Electronic Control - 0^{o}c to + 40^{o}c

See Accuracy Specifications

Storage Temperature

Sensor Head - 40^{o}c to + 55^{o}c
Electronic Control - 40^{o}c to + 55^{o}c
(batteries fully charged)

Humidity

Sensor Head - 100%, splash proof (oil and water) with cables connected (do not emerse)

Control Section - 100%

2.4 Measuring Capabilities

Rope Size and Construction
All steel wire ropes of any construction from 1/2 to 2 1/2 inches in diameter (12-64mm).

Rope Speed
0-600 ft./min. (0-3 m./s.) with 300-400 ft./min. (1.5-2.0 m./s.) as a preferred testing speed

Sensitivity
LMA - ± .5% change in metallic area
LF - a discontinuity of .1% of nominal rope metallic area

Accuracy
LMA - ± 2.5% of reading for all rope sizes and construction from 0°c to +30°c
± 5.% of reading from -20°c to +40°c
LF - peak signal repeatable with ±5% accuracy from 0°c to +30°c and ± 10% accuracy from -20°c to +40°c.

Accuracy specifications are referenced to readings at +20°c.

Detecting Length
Metallic area reduction/increase will be detected with the accuracy specified provided they exist over a length of 24 inches (610 mm.).

3.2 The Magnetic Circuit

The heart of the magnetic circuit is the rare earth magnets at each end of the sensing head. As shown in Fig. 3.2 the magnetic circuit is completed through the flux bar on one side and through the pole piece and rope under test on the other side.

There are 4 sets of adapter tubes with various IDs which fit against the pole pieces and which serve to decrease the air gap between the pole piece and rope under test. These are shown in Fig. 1.0.

The magnetic circuit in the Magnograph brings the portion of the rope between the pole pieces to a high level of static magnetic saturation. In this state the magnetic flux density will have a uniform distribution throughout the rope within the sensing head and will assume a constant value.

3.2.1 Metallic Area Measurement

As the magnetic flux density (B) within the rope is at a constant saturation value the total magnetic flux passing through the rope and pole pieces is directly proportional to the metallic cross-section of the rope. This flux is what is measured by the LMA Hall sensors.

When the metallic area of rope decreases or increases along its length the LMA Hall sensors will show decreasing or increasing voltage due to the change in metallic cross-section. The voltages generated by the Hall sensors are amplified and scaled in the electronic control section to produce outputs on the chart recorder and magnetic tape recording. These outputs show changes in the metallic area of the rope expressed as a percentage of the nominal rope metallic area.

3.2.2 Local Fault Measurements

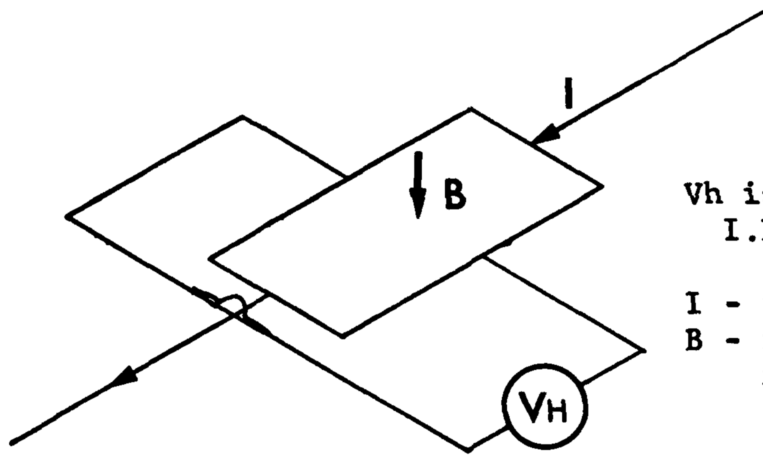
The magnetic flux induced into the rope under test will be contained by the rope unless there are physical discontinuities within it. Physical discontinuities such as broken or heavily nicked wires, pitting caused by corrosion, or wire ends produce small dipoles, as shown in Fig. 3.3. The resulting 'fringing field' of these dipoles protrude outside the physical confines of the rope.

3.0 Operating Theory

The intent of this section is to familiarize the user with the basis on which measurements of rope condition are made with the Magnograph. It touches on the magnetic principles involved and how they are applied to produce these readings. By necessity the analysis is simplified to stress the major considerations and effects of the principles involved.

3.1 The Hall Principle

The Hall Principle states that an electric potential will exist across a flat conductor carrying current if the conductor is subjected to a magnetic field. (refer to Fig. 3.1)



Vh is proportional to:
I.B

I - is the current
B - is the magnetic flux density

Fig. 3.1 Hall Principle.

The Magnograph uses this principle to measure metallic area and localized faults. The semi conductor Hall Effect Sensors used provide quite large and stable hall voltages and allow very small changes in flux density (B) to be measured whether they are static or dynamic in nature. The magnetic circuit and the placement of the Hall devices is shown in a cross-sectional view of the Magnograph in Fig. 3.2.

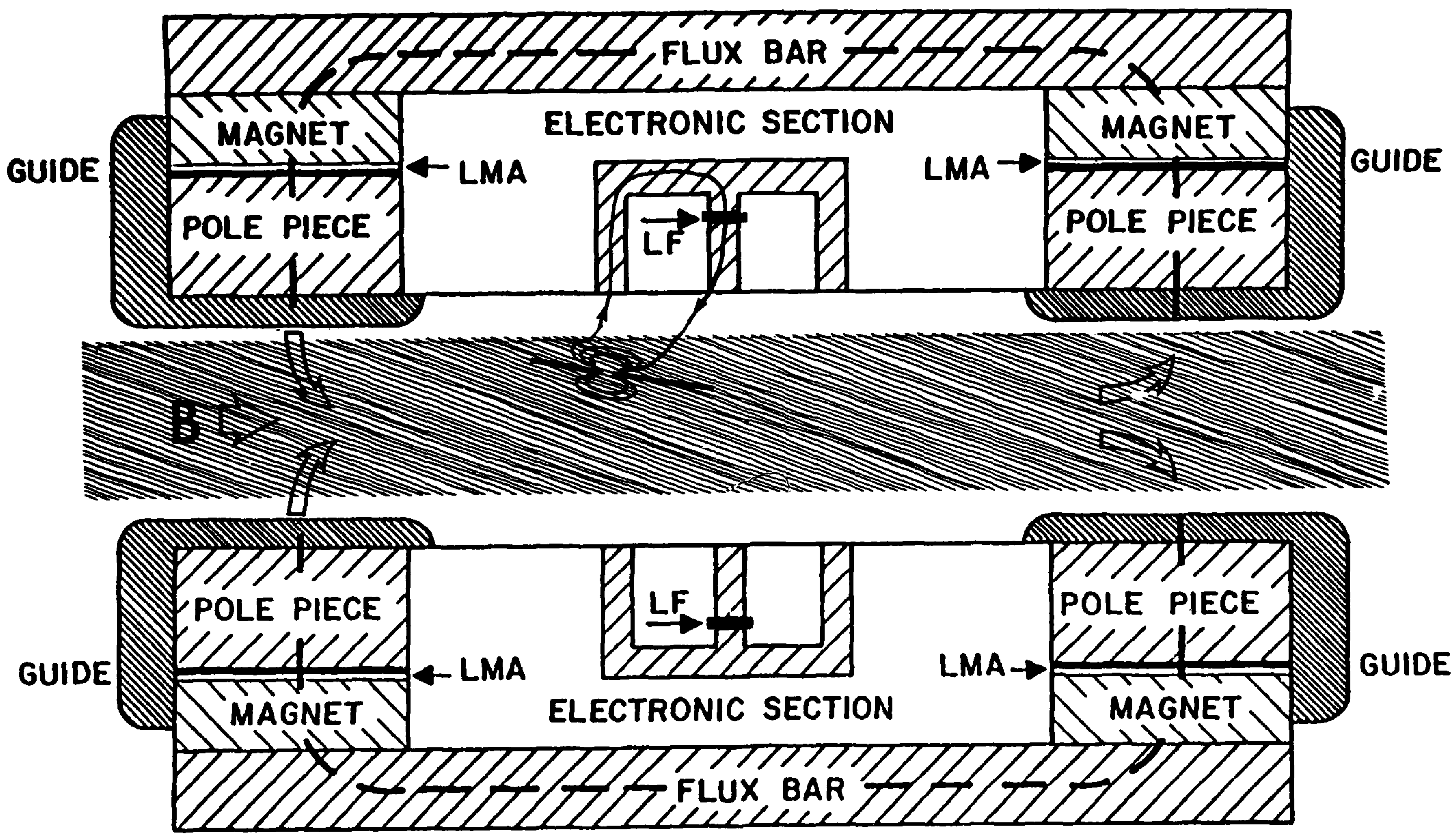


Fig. 3.2 Cross-sectional view of Magnograph sensor head. Shows LMA (loss of metallic area and LF (local fault) sensor placement and magnetic flux distribution within a rope under test.

This 'fringing field' passes the E shaped LF magnetic circuit and induces a positive voltage in the Hall sensors and then a negative voltage. This is illustrated in Fig.3.4 (a) - (d)

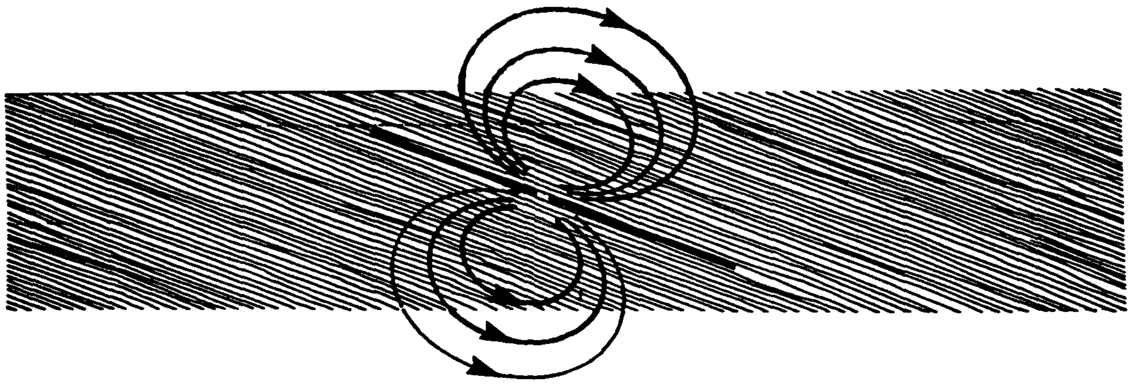


Fig. 3.3 Dipole & fringing field created by broken wire

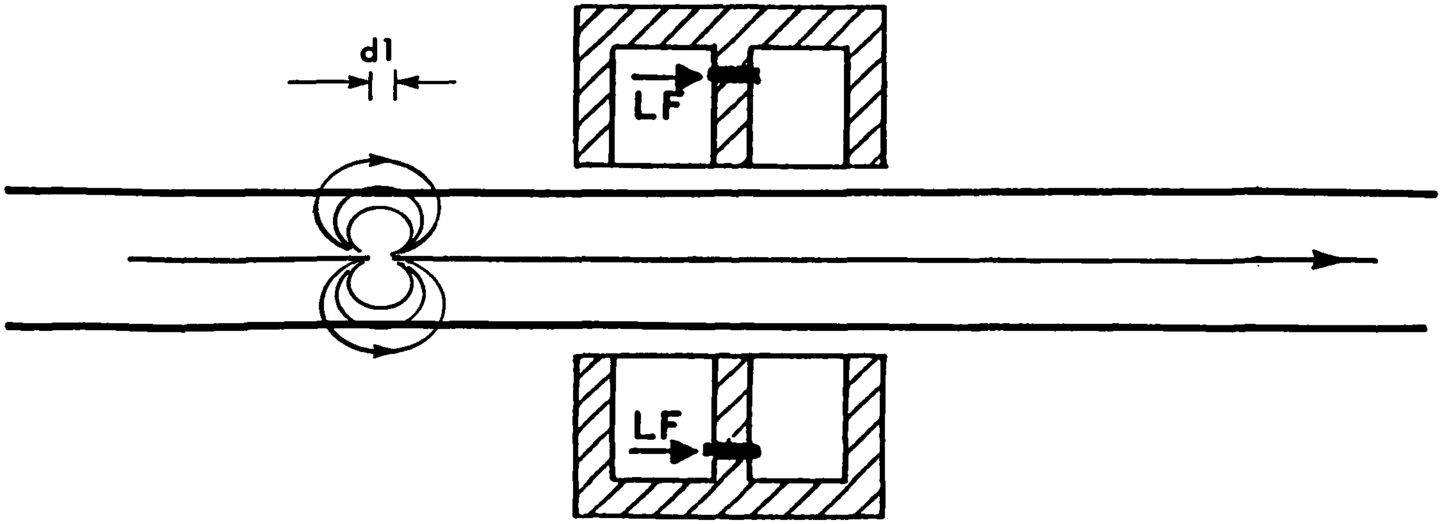


Fig. 3.4(a) Dipole fringing field before entering LF section.

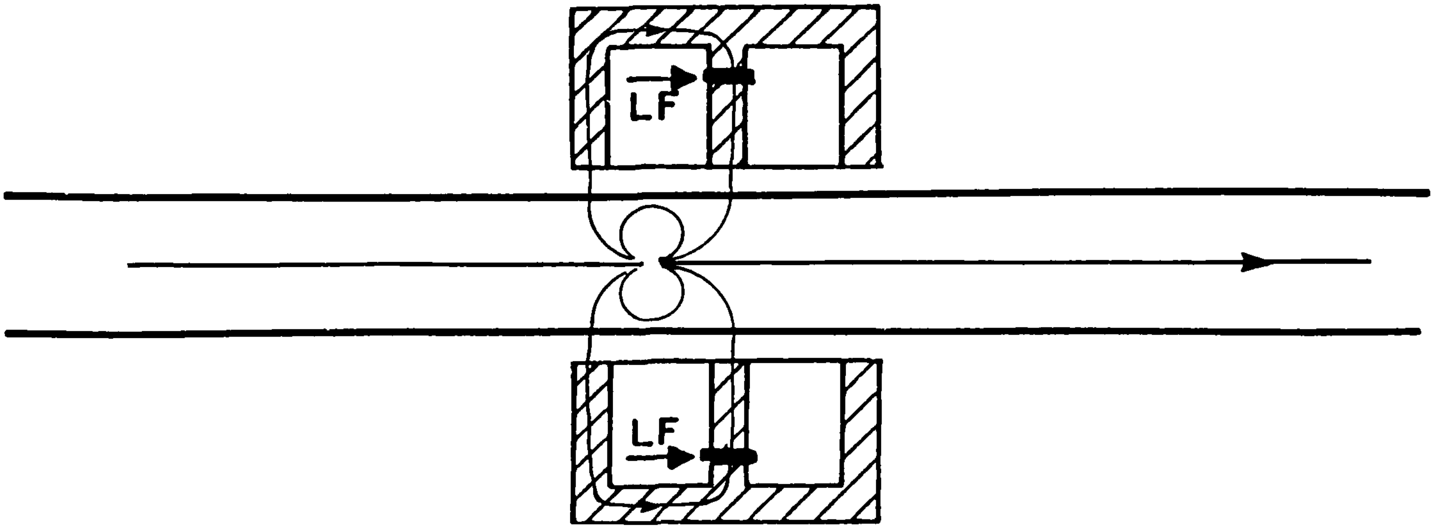


Fig. 3.4(b) Dipole fringing field entering first half of LF section

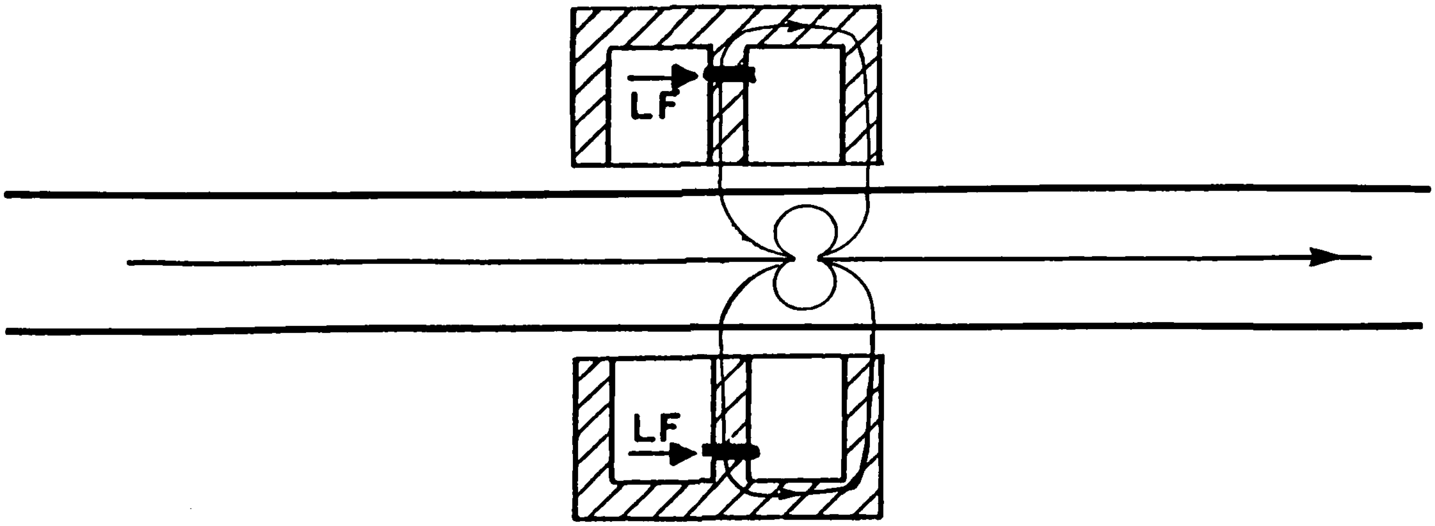


Fig. 3.4(c) Dipole fringing field entering second half of LF section

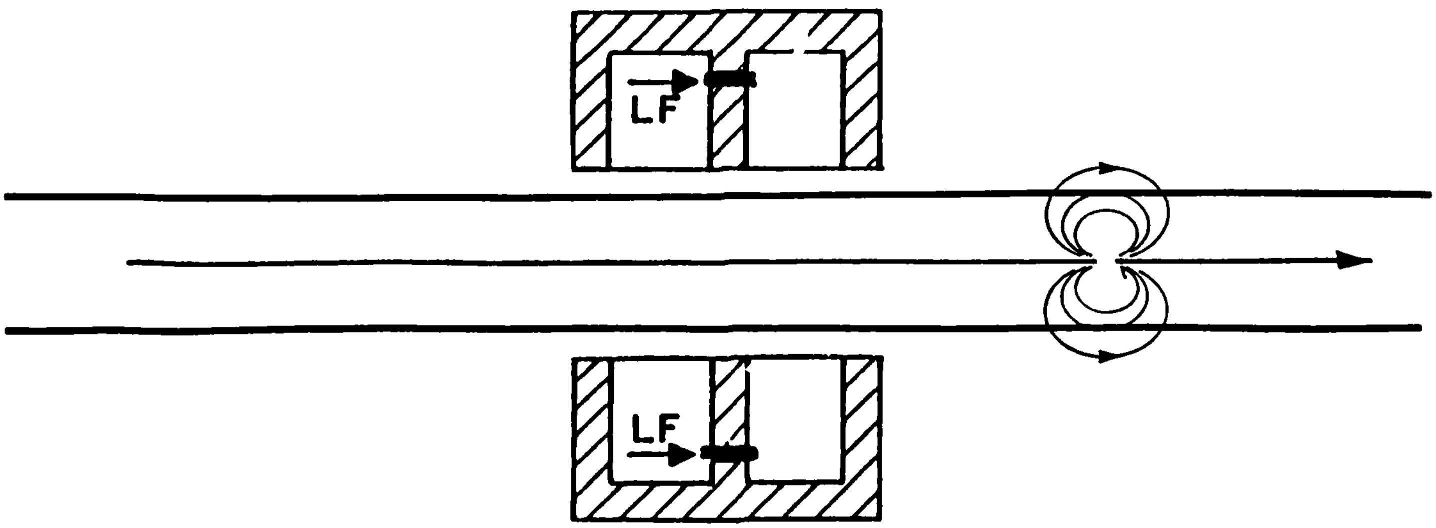


Fig. 3.4(d) Dipole fringing field leaving LF section

The resulting chart recorder trace for a broken wire fault will appear as in Fig. 3.5.

The resulting chart record of Fig. 3.5 is typical of a short dipole type of defect where dl is small. Defects of this type are wire breaks, deep wire nicks, and corrosion pitting. Wires which are missing in a cable will produce a dipole which has a very large value for dl. This will serve to stretch out the zero crossing shown in Fig. 3.5 so that it will appear as in Fig. 3.6.

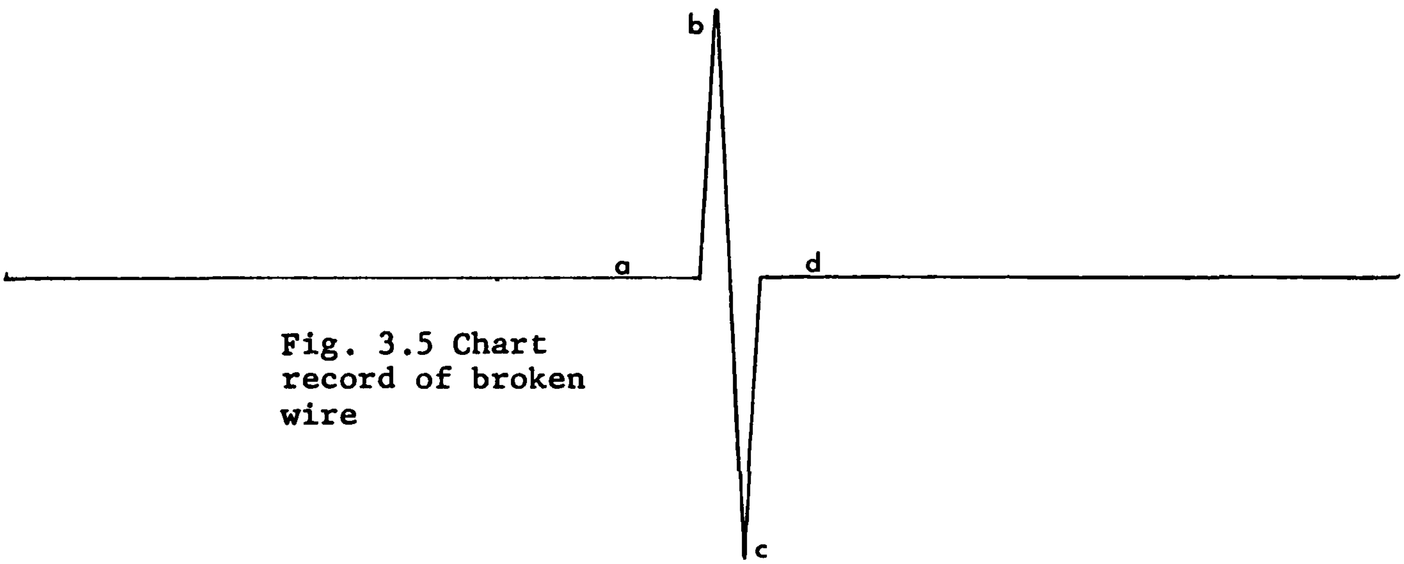


Fig. 3.5 Chart record of broken wire

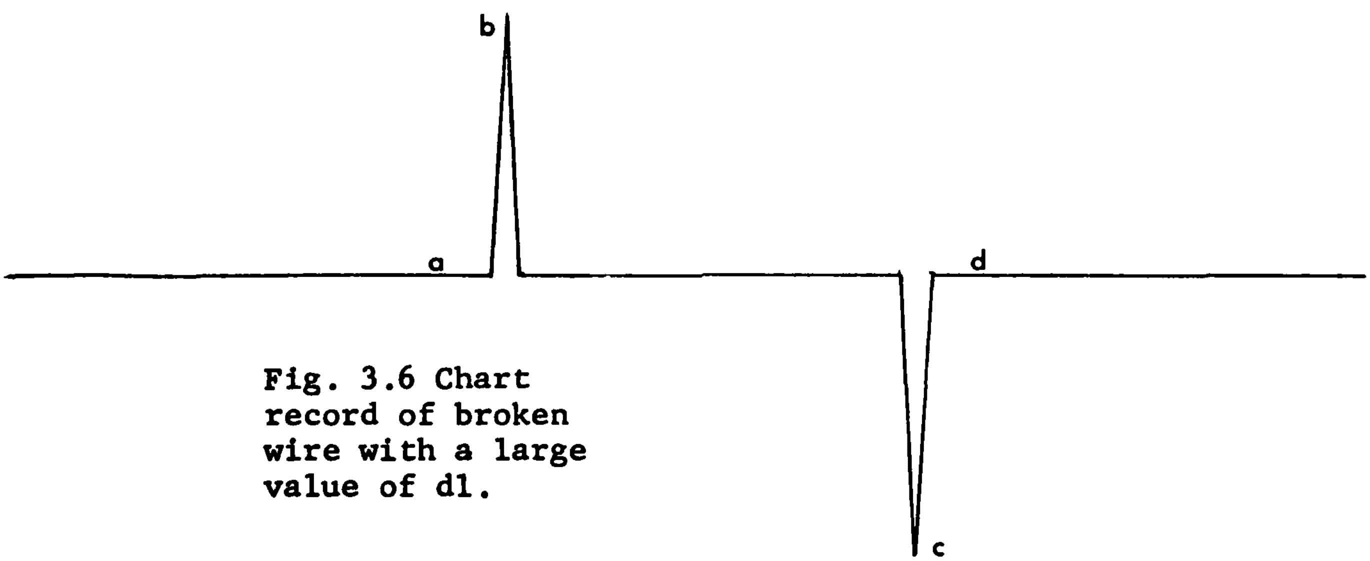


Fig. 3.6 Chart record of broken wire with a large value of dl.

An example of a missing wire is shown in Fig. 3.7.

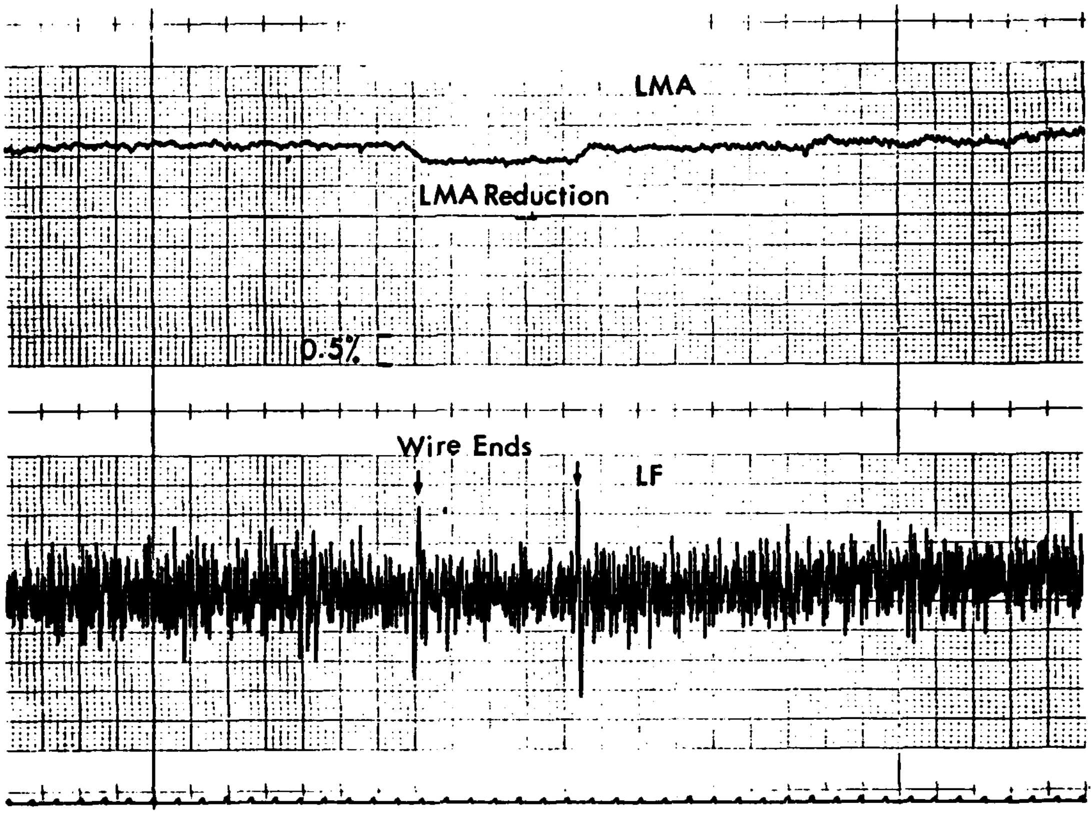


Fig. 3.7 Missing Wire in 1" full locked coil hoisting rope.

3.2.3 Static Measuring Capabilities

The Hall sensor measures field statically or dynamically. This allows the Magnograph to be virtually insensitive to rope speed. Maximum rope speeds are controlled by the speed of response of the recording medium and the bandwidth of the control instrumentation rather than the magnetic circuit.

This ability is most useful when pin pointing local faults as the sensing head can be brought very slowly to a fault and stopped on it.

3.3 The Advantages of High Magnetic Saturation

3.3.1 The Magnetics of Materials

Wire ropes are made of carbon steel which exhibit Ferromagnetism and Hysteresis. A magnetic induction curve for this type of material is shown in Fig. 3.8.

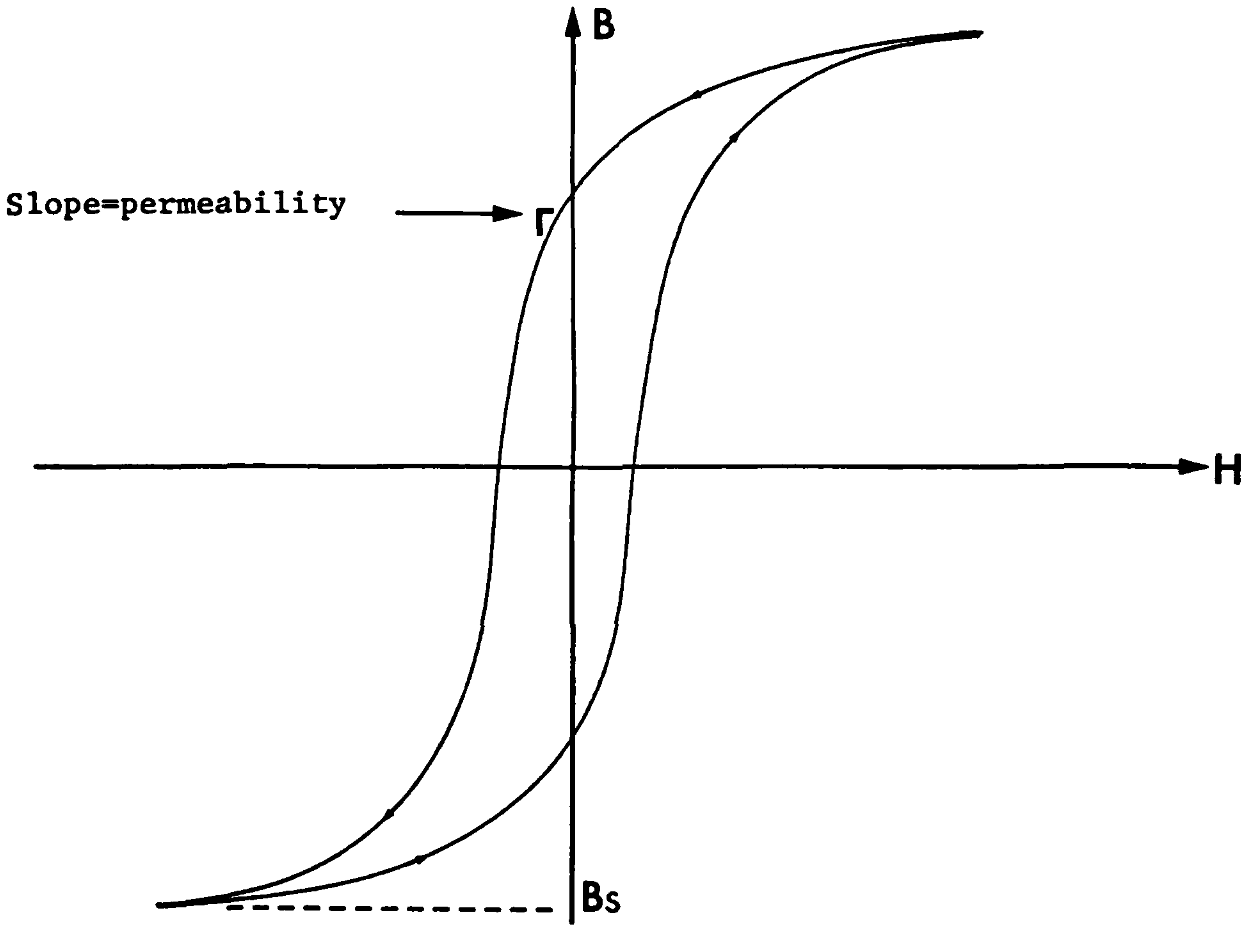


Fig. 3.8 Magnetic induction curve for carbon steel

The slope of the B-H curves at any point is called the permeability $\mu = B/H$. The value of μ changes with the slope of the B-H curve. At flux level Bs the material is magnetically saturated and μ drops to a very low value.

The inverse of μ is related to the 'reluctance' R of the magnetic material:

$R = K/\mu$; As μ decreases, R increases.

As R increases in a material it shows a higher resistance to the flow of magnetic flux (B) for a given Magneto Motive Force H. This is an advantage for the LF sensing section of the Magnograph as a dipole created by a local fault will experience a very small 'short circuit' effect by the surrounding wires. This allows detection of breaks deep within a large rope.

3.3.2 Permeability Changes in Magnetic Materials

The magnetic behavior of steel in wire rope is affected by factors other than the operating point of the magnetic circuit used to test it. Temperature and tension change the permeability of the steel and oxides associated with corrosion can contribute to the total flux flowing within a wire rope. The effects of temperature and tension on permeability are very pronounced at low values of magnetic flux density.

At very high levels of magnetic flux density the effects of temperature and tension are negligible. The contribution to the total flux within a rope under test due to corrosion is also negligible when compared with the total flux due to the steel alone. For these reasons, the metallic area readings of the Magnograph do not require 'interpretation' to remove the effects of tension, temperature or corrosion.

4.0 Operating Instructions

These operating instructions are intended as a guide to the use of the Magnograph. It is aimed at familiarizing users with the controls and procedures that will generally be followed during a test. Users are encouraged to improvise and should contact Heath & Sherwood (1964) Limited if there are any questions on application.

4.1 Transporting, Handling and Charging

The plywood containers used to ship the instrument are designed to provide protection for it. They should be used when the instrument is being transported over long distances, shipped by air or when it will be subjected to rough handling. The instrument should be considered as sensitive electronic equipment and handled accordingly during testing and transportation.

On receipt of the equipment it should be charged for 14 hours. This should also be done after 8 hours continuous use or when the battery indicator shows a low battery condition. (see section 4.2)

The battery charger has been designed to 'trickle charge' the batteries and will not over charge them. For further information on battery care, refer to section 5. of this manual.

Before charging is started the user should ensure that the Electronic Control and Recording sections have been set to the AC voltage that will be used. The AC voltage used to charge the instrument is switch selectable by toggle switches on the Electronic Control and Recording Section chassis. Units will be shipped set for the AC voltage requested by the customer.

4.2 Front Panel Controls - Electronic Control Section

Refer to Fig.4.1

1. Power ON/OFF Switch - this should be off during charging and when connecting or disconnecting sensor head.

2. AC Power Connector - centre pin grounded to case.

3. Sensor Head Connector - used to connect the Sensor Head to the Electronic Control Section.

4. Chart Recorder Connector - used to connect the Chart Recorder to the Control Section.

5. Battery Check Push Button - indicates battery voltage on LMA meter when depressed.

6. LMA Meter - indicates LMA on record or playback

   Note - this should be used as an indicator only; accurate readings should be taken from the chart recorder.

7. Metric/English Switch - In the 'Metric' Position:
   - measured length is in meters
   - rope speed is in meters per second
   - meter marks are generated on the chart recording.

   In the 'English' Position:
   - measured length is in yards
   - rope speed is in feet per minute
   - Yard marks are generated on the chart recording.

8. Rope Direction Switch - changes direction of counting on measured length counter.

9. LMA Gain Potentiometer:	-Set according to LMA gain chart. -calibrates chart record to show metallic area losses as a percent of nominal rope metallic area.
10. LMA Zero Potentiometer:	-Used to zero the LMA signal when starting a test. Its setting is related to rope weight and LMA gain by the LMA gain chart.
11. LMA Calibrated Offset	-Used to shift the LMA signal by a fixed amount during testing. (affects chart recorder feed only).
12. LF Gain Potentiometer:	-Sets the internal gain of the electronic control section for the LF channel -setting depends on rope size, construction and condition.
13. LF Zero Potentiometer:	-Used only in the 'static' mode of testing to zero the LF trace.
14. Compression Band Switch	-used to 'compress' lower amplitude noise on the LF trace -this function is available on record only.
15. LF Meter	-Used for zero adjustment of the LF trace and as an indicator of LF signal.
16. Static/Dynamic Switch	-Tests can be run in 'Dynamic' mode when rope speeds are above 100 ft/min (.35m/sec); below this speed 'static' setting should be used.
17. Measured Length Counter	-Shows distance from starting point of the test.

18. Wire Rope Speed - shows speed of rope through the head.

19. Tape Counter - shows position on cassette tape.

20. Record/Play Switch - sets the electronic control section and tape transport in either record or play mode.

21-25. Cassette Recorder Controls - ensure the 'Record' button is depressed when initiating recording.

26. Cassette Tape Transport.

27. External Battery Connection.

28. External Battery Indicator:- will illuminate when the external battery is connected with the proper polarity.

Prior to any testing the battery condition should be checked. Depress the battery test switch and observe the battery voltage on the LMA meter. The 'BATT' marking on the meter corresponds to 11.V. If the battery condition is at or below this level the batteries should be recharged. If necessary the Electronic Control and Chart Recording sections can be run from an AC source. This is not recommended where the AC is electrically noisy.

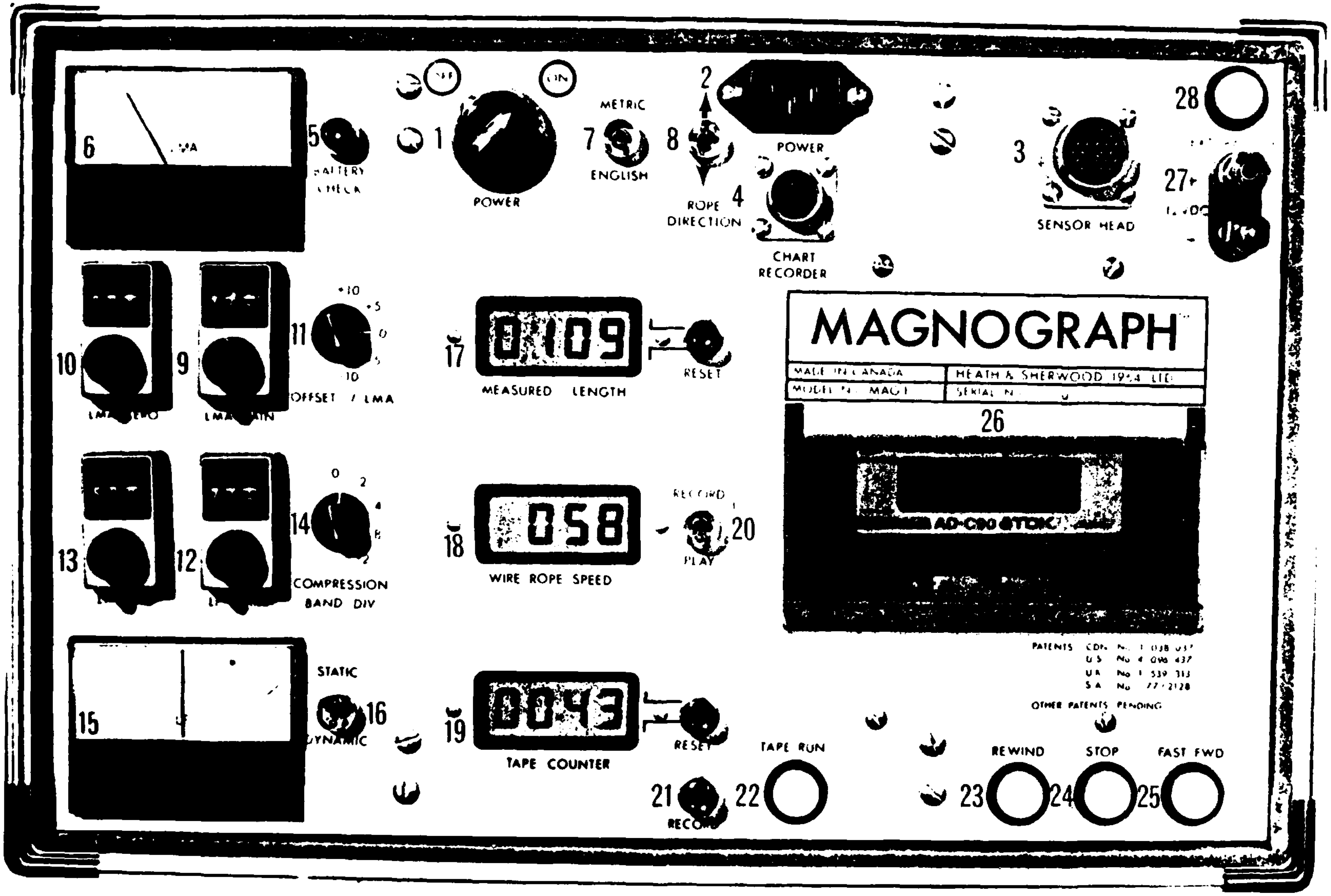


Fig. 4.1 Front Panel Controls Electronic Control Section

4.3 Front Panel Controls - Chart Recorder Section

Refer to Fig. 4.2

1. AC Power Connector - centre pin grounded to case.

2. LF Channel Output - LF signal present at these terminals.
   - also used for zeroing chart recorder LF Channel.

3. LMA Channel Output - LMA signal present at these terminals.
   - also used for zeroing the chart recorder LMA channel.

4. Chart Speed Selector - Select 'Time Base' chart speed. Used in 50 mm/sec. position when 'Proportional Drive' is used.

5. Chart Recorder Connector - used to connect the Chart Recorder section to the Electronic Control Section.

6. Proportional Drive Selector Switch - synchronizes chart speed to rope speed.
   - should not be used at speeds less than 10 ft/min. (.05 m./s.)
   - requires selection of the 50 mm/sec. time base on the recorder.

The chart recorder controls for position and sensitivity are used to adjust and calibrate the chart record. The variable sensitivity potentiometers should be in the xl position at all times. The multi position sensitivity switches should be set as follows:

LF Channel - 20 mv/mm when recording; higher sensitivity may be used on 'Playback'

LMA Channel
- 5 mv/mm for a full scale LMA sensitivity of 25%.
- 2 mv/mm for a full scale LMA sensitivity of 10%.
- 1 mv/mm for a full scale LMA sensitivity of 5%.

For further explanation of the chart recorder controls refer to Gould manual No. 15-806325-00.

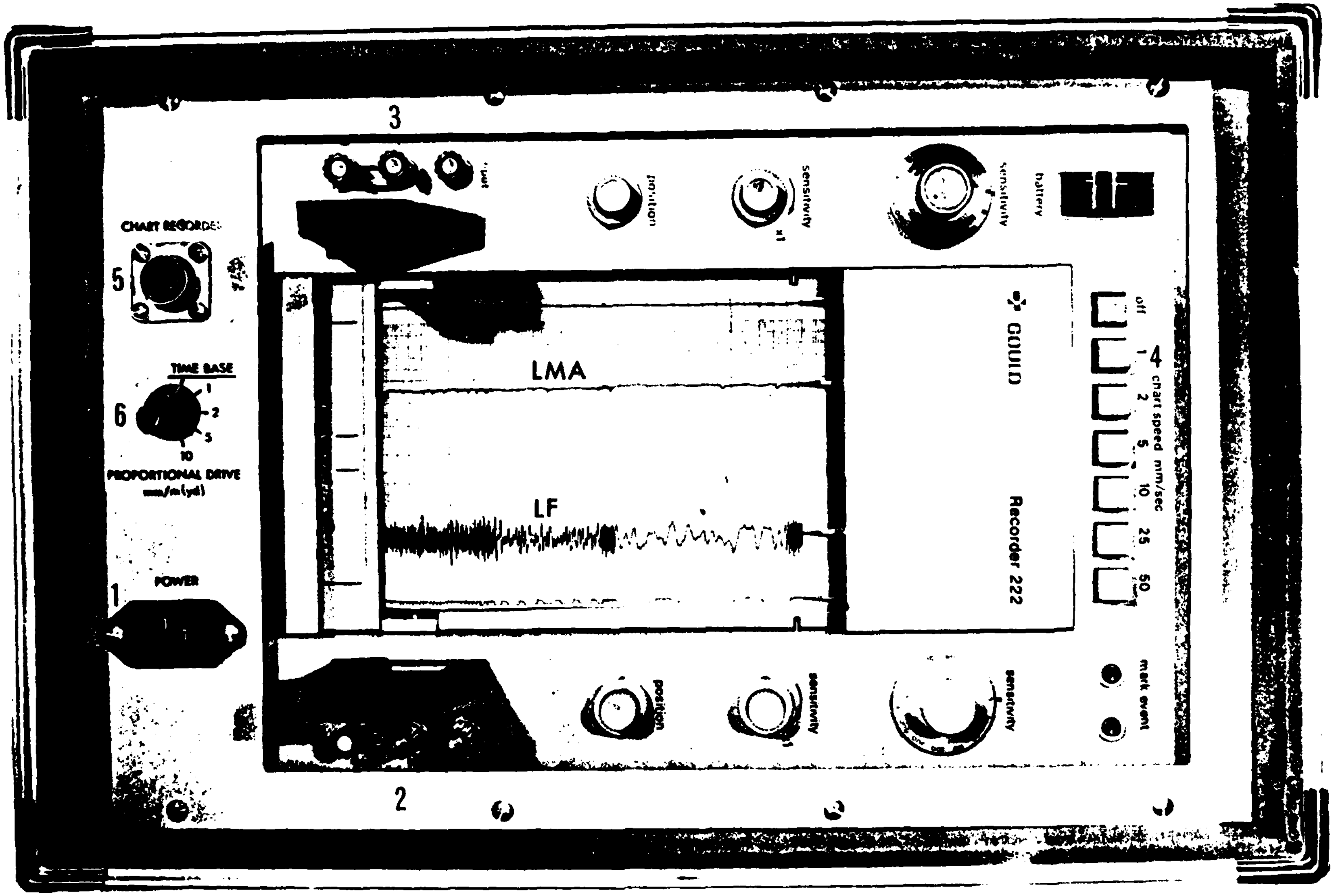


Fig. 4.2 Front Panel Controls, Chart Recorder

4.4 Conducting a Field Test

Choosing the Proper Rope Guide and Adapter Tube

The instrument is equipped with 5 sets of rope guides and 4 sets of adapter tubes. The smallest set of guides and tubes that will allow free movement of the rope should be used in the sensor head when testing a rope. Table4.1 gives a general guide line for the rope guides used. Adapter tubes should be chosen to fit the rope guide selected.

Table 4.1

Rope Guide	Rope O.D.
A	1/2 - 3/4 in (12-20 mm)
B	3/4 - 1 1/8 in (20-27mm)
C	1 1/8 - 1 9/16 in (27-39mm)
D	1 9/16 - 2 in (39-51mm)
E	2 - 2 1/2 in (51-64mm).

Note - Rope Guide E does not require an adapter tube.

4.4.1 Installing and Changing Adapter Tubes (Refer to Fig. 4.3)

With the sensor head open undo the knurled screws holding the rope guides in place and remove the rope guides.

Insert a screw driver blade into the hole at the end of the adaptor tube and pull one end up. The tube can then be removed from the sensor head by hand.

To install the new adapter tube the same procedure is followed in reverse. When installing the tube be sure that the end of the tube is aligned with the end of the sensor head so that the small 'locating' pins on the adaptor tube will mate with the locating holes on the head.

Note - The magnetic attraction of the head is very strong. Caution must be used to prevent injury.

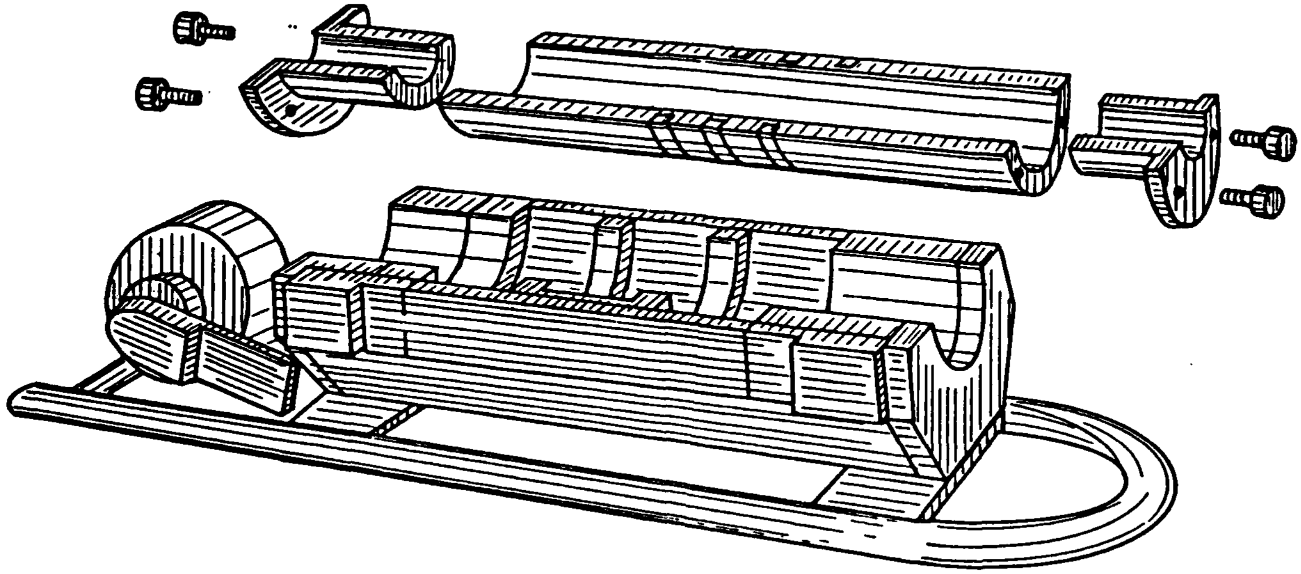


Fig. 4.3 Adapter tube and rope guide installation

4.4.2 Installing & Positioning the Sensor Head on the Rope

The sensor head can be mounted in any position for testing. When positioning on the rope care should be taken that the wheels are free to move and that the head is secured to prevent it being carried away by lumps of lubrication or protruding wires. The rope guides act as slip planes between the rope and the head and are capable of taking the weight of the head on them.

It is advisable to locate the head so that no large pieces of metal are closer than one foot to it, the sides in particular. This can cause some distortion in the magnetic field which may compromise the readings.

A typical vertical testing arrangement is shown in Fig. 4.5

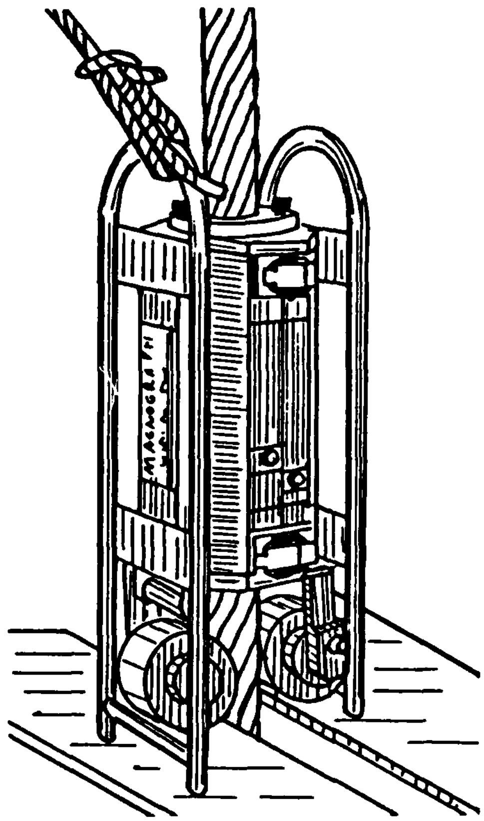


Fig. 4.5   Typical vertical testing arrangement

The cable which attaches to the sensing head has two 9 pin connectors and one 5 pin connector. The 9 pin connectors connect to the receptacles on the side of the head and the 5 pin connector to the arm of one wheel. The cable should be routed as per Fig. 4.6 to allow the head to be installed on the rope when the connectors are attached.

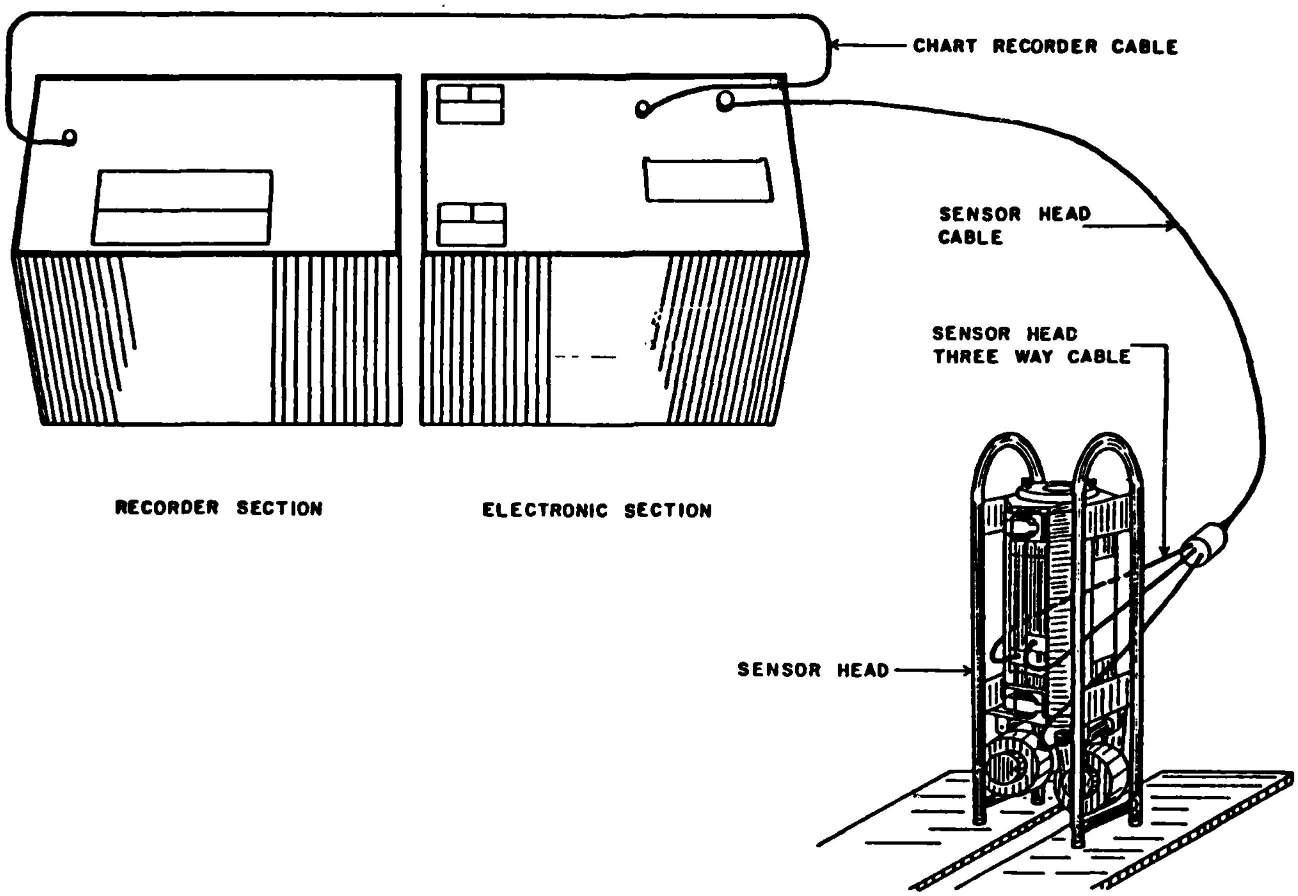


Fig. 4.6 Cable routing

With the cable connected to the head, install it on the rope by undoing the two clasps and bringing one half of the head to the rope so that the rope rests in the rope guides. Close the head and refasten the clasps.

Note - During connection and disconnection of the head the electronic control section should be turned off.

4.4.3 Running the Test

When the sensor head and recorder have been connected to the electronic control section it may be turned on. Allow it to warm up for 30 sec.

Adjusting the instrument for the rope being tested is carried out as follows:

i) Start the chart recorder in the Time Base mode, at some convenient chart speed. (1mm/sec.)

ii) Set the multi position sensitivity switch on the LMA Channel for the desired LMA sensitivity. This should be done so that the highest and lowest LMA readings will remain on the chart. The sensitivity settings and their corresponding LMA sensitivity is shown in Table 4.2.

Table 4.2

Chart Recorder Sensitivity	LMA Sensitivity
5mv/mm	25% LMA full scale (.5% LMA/mm.)
2mv/mm	10% LMA full scale (.2% LMA/mm.)
1mv/mm	5% LMA full scale (.1% LMA/mm.)

iii) Zero both channels by using the shorting plugs provided in the LMA and LF Channel Outputs (See Fig.4.2) and by adjusting the chart recorder position controls. The LF channel should be zeroed in the centre of the trace and the LMA channel, 2 large divisions above the centre of the trace so that both positive and negative LMA changes may be kept on the graph.

iv) Switch the Record/Play switch to the 'Play' mode.

v) Adjust the LMA Zero Potentiometer to give the zero reference established in iii) or to show zero on the LMA Meter.

vi) Adjust the LMA Gain as per the graph in Fig. 4.8. Re-adjust the zero and gain if necessary.

vii) Select either 'Static'or 'Dynamic' on the Dynamic/Static switch depending on the rope speed anticipated. If the 'static' mode of operation is chosen adjust the LF Zero potentiometer to give the zero reference chosen in iii) or to show the centre of the scale on the LF meter. Adjust the LF gain as per the discussion in section 4.5.1.

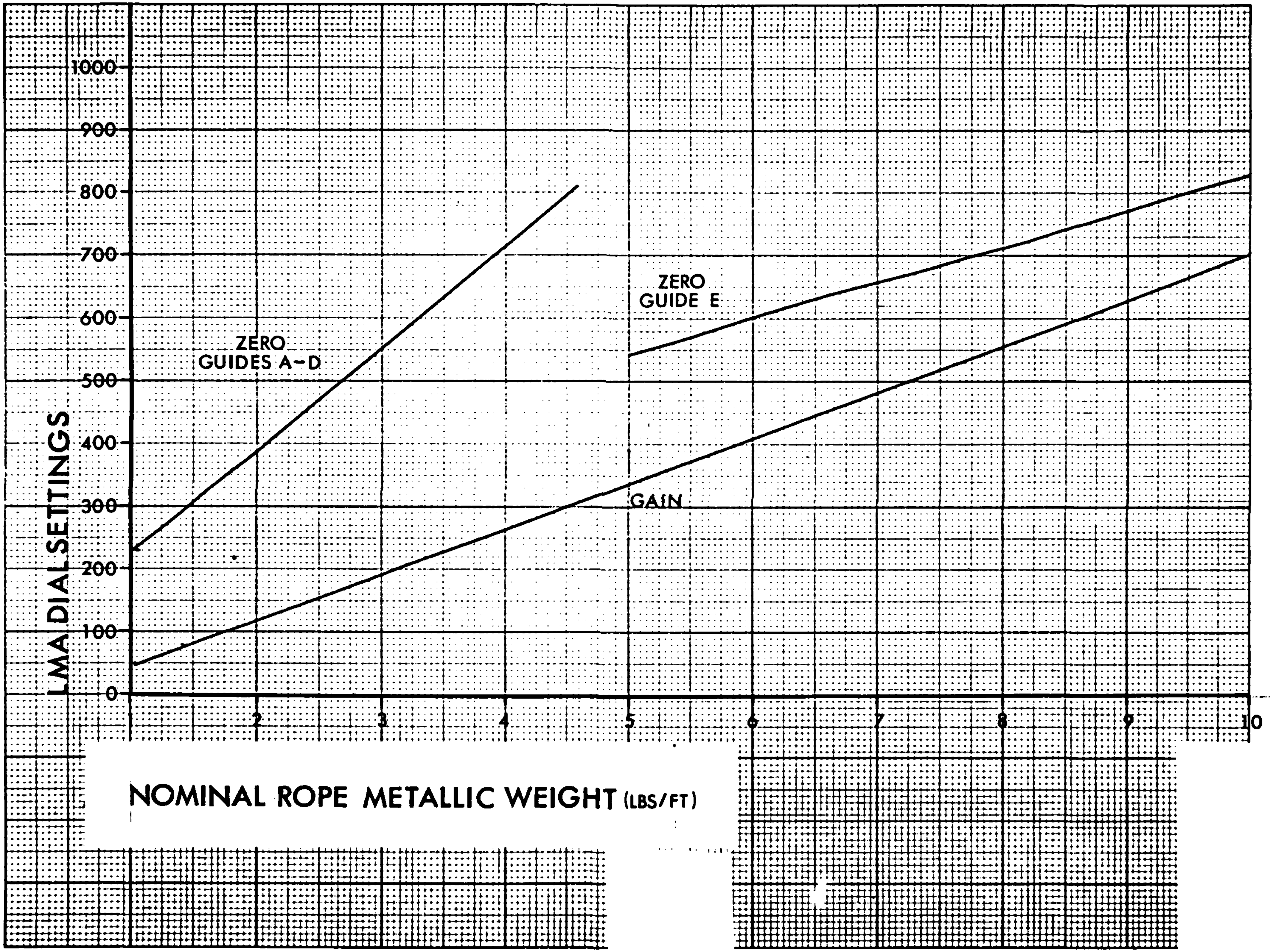
viii) Set the position on the Rope Direction Switch to correspond to the rope direction (with the switch in the up position a rope moving from the top of the sensor head toward the wheels will cause the measured length counter to count up.)

ix) Set the Metric/English switch to the desired position, the Calibrated Offset to 0 and the Compression Band Switch to the desired amount of compression (see section 4.5.3 for further explanation of the use of this setting).

x) If a tape recording is to be made load a cassette into the tape transport. Press the red Record Button and the Tape Run button and allow the tape to advance passed the leader.

xi) Zero the Measured Length and the Tape Counter displays.

xii) Start the rope.


LMA DIAL SETTINGS
1000
900
800
700
600
500
400
300
200
100
0
ZERO GUIDES A–D
ZERO GUIDE E
GAIN
2
3
4
5
6
7
8
9
10
NOMINAL ROPE METALLIC WEIGHT (LBS/FT)

4.5 General Considerations for Testing

It is best to start a test on a section of rope which is known to be in good condition. This will give the best calibration for nominal rope weight on the LMA trace and will allow the LF trace to be calibrated for an area where the LF signal will be relatively clean.

4.5.1 LF Signal Generation

The local fault (LF) reading is affected by many things. Magnetic dipoles which the Hall sensors will detect are formed by broken wires, nicks, corrosion and wear. Broken wire dipoles and how they show on the chart record is a function of how large the wire is and how large the separation is between the ends of the break. In general the magnitude of a broken wire signal will increase as the separation between the ends increases to the point where the zero crossing becomes a plateau as shown in Fig. 3.6. Broken wires with the ends 'butted' together will not show on the chart record as no dipole is produced. A large broken wire with the same end separation will show a larger signal than a small wire.

Wire rope, when new, will show a low level local fault signal associated with the lay of the rope. The amplitude of this signal is a function of the size and construction of the rope. The signal is higher for larger ropes of the same construction and is higher for stranded ropes than for locked coil ropes.

The lay noise and a broken wire signal are shown in Fig. 4.9 on the left. On the right of Fig. 4.9 is the chart recording of the same rope in an area where the wear is high and corrosion is present. The LF Gain is the same for both sections of the graph.

As can be seen the LF 'background noise' increases dramatically with wear and corrosion on the rope and in this case is assuming the magnitude of the broken wire signal on the left part of the chart. As rope wear increases the broken wire signal may become lost in this 'background noise'.

The increase in the 'envelope' of the LF trace is an important qualitative indication of rope condition. The increase with time in the signal's 'envelope' is an important piece of rope history to keep track of as its growth will accelerate as the rope nears the end of its life.

Due to the many factors affecting the generation of LF signals a graph of gain setting vs. rope size and construction is of little use. The LF gain setting will depend on the rope size, construction, and its state of wear. Section 4.5.2 sets out general 'rules of thumb' which should be followed to gain the most information from the LF trace.

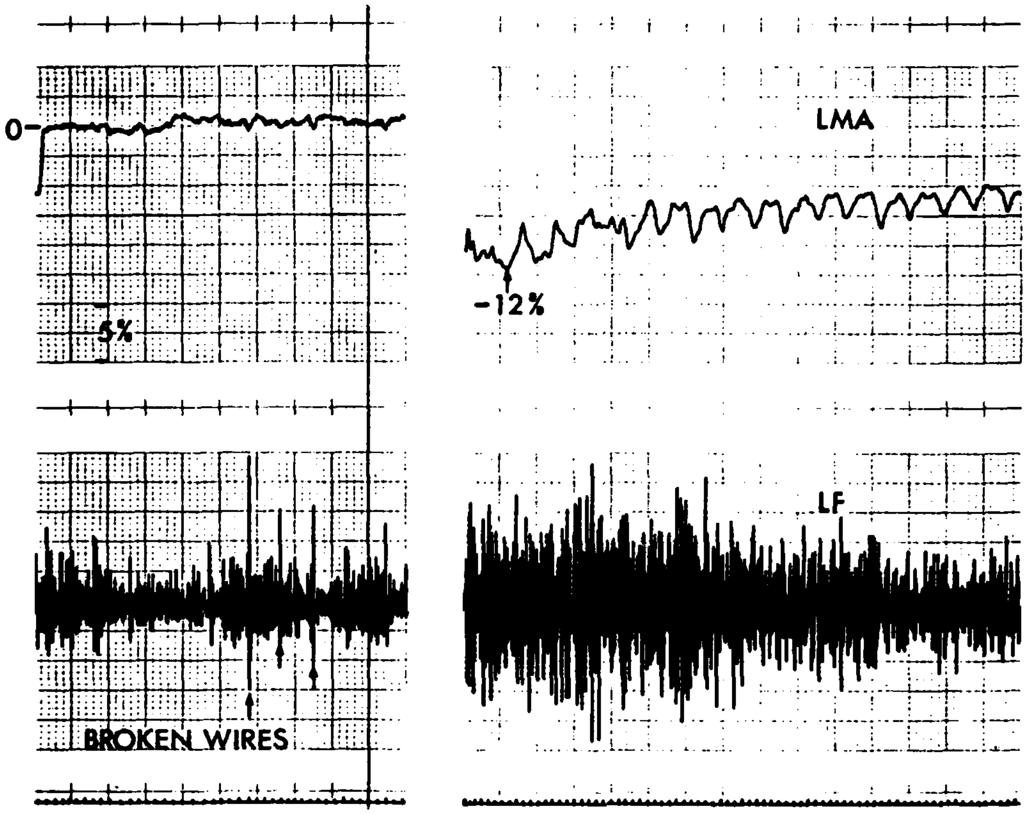


Fig. 4.9 1 1/8" 6x27 Hoisting Rope.

4.5.2 LF Gain Potentiometer Setting

On ropes with very little wear the LF Gain should be adjusted to show $\pm$ 3 small divisions of signal on the chart recorder. This will allow significant local faults to be quite visible. With rope wear this initial setting will cause the LF trace to go off scale in sections where corrosion and wear are heavy. The gain should be reduced to ensure that these areas are mostly on the chart so that only occasional peaks go off the chart limit.

Areas of the rope that have little wear and for which a higher amplification can be used can be tested again at a higher amplification or can be re-run from the tape with a higher chart sensitivity (see section 4.6).

As the user becomes more familiar with the ropes under test the setting of gain to keep the LF signal on the chart will be quite straight forward.

The change from test to test of the LF trace should be watched carefully and the gains used for successive tests should be kept track of to establish the rate of increase of the LF signal. In Fig. 4.10 the gain of the LF amplifiers vs. the Gain Potentiometer setting is shown. To relate the changes in amplitude of the LF trace with successive tests, the amplitude change and any gain change should be noted so that an increase in the 'envelope' of rope noise can be kept track of. To find the total 'envelope' change take the change in the 'envelope' from the two tests and multiply by a factor of New Gain/Original Gain. This change in the 'envelope' of rope noise should form part of the history of the Rope.

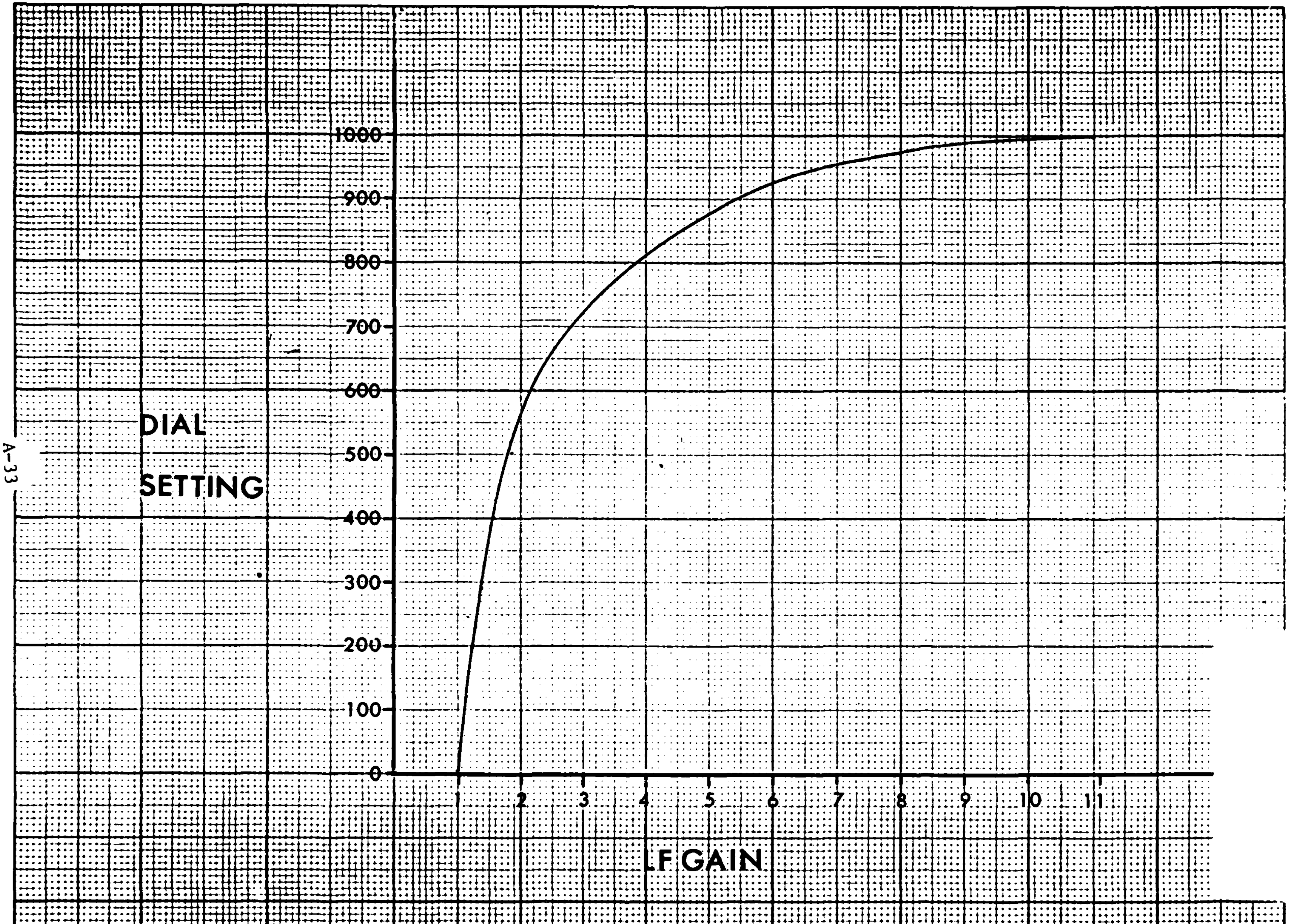

1000
900
800
700
600
500
400
300
200
100
0
DIAL
SETTING
2
3
4
5
6
7
8
9
10
11
LF GAIN

FIG. 4.10

4.5.3 Use of the Compression Band Switch

The compression band switch controls the amplification of the LF signal in a manner that will reduce signals with an amplitude below a certain number of divisions on the chart but will leave the gain unchanged for signals over this number. As an example, a setting of 4 on the Compression Band Switch will reduce signals of $\pm$ 4 small chart divisions by a factor of 10 but will leave signals above $\pm$ 4 divisions with their original gain. This feature is used to accentuate the higher amplitude LF signals. Caution is required in the use of the compression control and it should only be used when familiar with the instrument and the rope under test. The compression control works only in the 'Record' mode and the 'compressed' LF signal will be recorded on the tape. If uncertainty exists on what compression setting will be most valuable for a particular rope the compression switch should be left at zero as LF signals which are of interest but which have been 'compressed' are not retrievable from the tape recording of the rope.

4.5.4 Use of Proportional Drive Chart Control

The chart can be advanced proportionally with rope speed during a test or tape replay. To do this select a proportional drive setting on the Chart Recorder Section and depress the 50mm/sec. chart speed button. The chart will advance and 'sync' itself to the rope speed.

The proportional drive requires a few yards (meters) to lock into the rope speed and initial rope speeds will not be accurately represented.

4.5.5 Distance Markers on Chart Recorder

There are 2 event markers on the chart recorder which indicate distance travelled along the rope. The lower event markers (on the side of the LF trace) marks every yard or meter. The upper event marker (on the side of the LMA trace) marks every 50 and 100 yards or meters. The 50 y/m marks are short pulses and the 100 y/m marks are long pulses. The 50 and 100 y/m marks will only be indicated when the rope measured length counter is counting up. The y/m marks have 2 polarities as shown in Fig. 4.11.

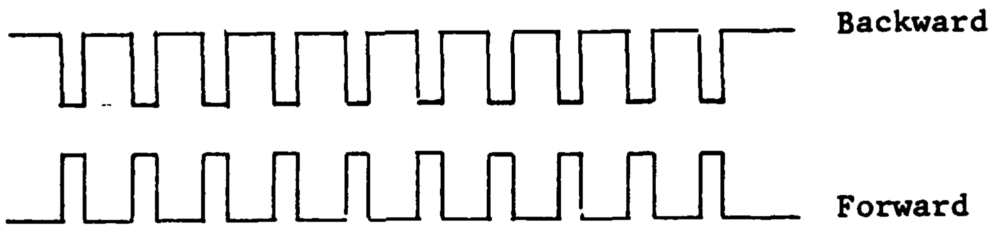


Fig. 4.11 Yard/Meter Marks.

The 50 and 100 y/m marks are ~~not~~ recorded on tape as the y/m marks are and are used to locate distance along the rope from the beginning of the test.

4.6 Running a Chart Record From Tape

Rope testing can be done without the Chart Recorder and the information can be recorded on tape only. Conversely a tape recording of a rope test is not essential but forms a convenient way of storing rope data, and allows replay of the rope test for further investigation.

When a tape is made of a rope test the LMA, LF and yard or meter marks are recorded on the tape. This allows a further investigation of the test using increased chart speed or sensitivity. When a test is underway, areas of the rope that warrant further information should be indicated with the tape counter number so that they can be located on the tape afterwards. The tape counter will help to locate the area of the fault on the tape, but will not pinpoint it exactly as there is some slippage in the tape transport.

Note - Do not allow tapes to come close to sensor head as the strong magnetic field will erase them.

To re-run a test from tape the following procedure is used:

i) Connect the Chart Recorder Section to the Electronic Control Section.
ii) Turn the Electronic Control Section on and set the chart recorder to the desired chart speed or proportional drive setting (see sections 4.3 & 4.5.4).
iii) Set the Record/Play switch to the 'Play' mode and insert the cassette.
iv) Zero the chart recorder channels as at the beginning of a rope test.
v) Use the tape transport controls to locate the area of interest and start the recorder with the 'Tape Run' button.

The zero references for the LMA and LF Channels may require repositioning with the chart recorder controls.

Note - High quality recording tape should be used. TDK type AD is recommended.

4.7 Rope Magnetization

The strong magnetic field within the Magnograph sensing head will leave remnant magnetism in the rope. This remnant magnetism decreases somewhat with time and working of the rope in use. The presence of remnant magnetism in the rope causes a shift in the LMA zero as a result of a redistribution of the magnetic flux from the auxiliary field outside the sensing head to the field inside the sensing head.

The effect of the presence of remnant magnetism on the LMA readings can compromise the readings of the LMA channel if not properly accounted for.

In Fig. 4.12 the sensor head and its associated magnetic fields are shown for a rope with no remnant magnetism in it. (There may be small amounts of remnant magnetism in the cable due to the earth's magnetic field but these will be insignificant).

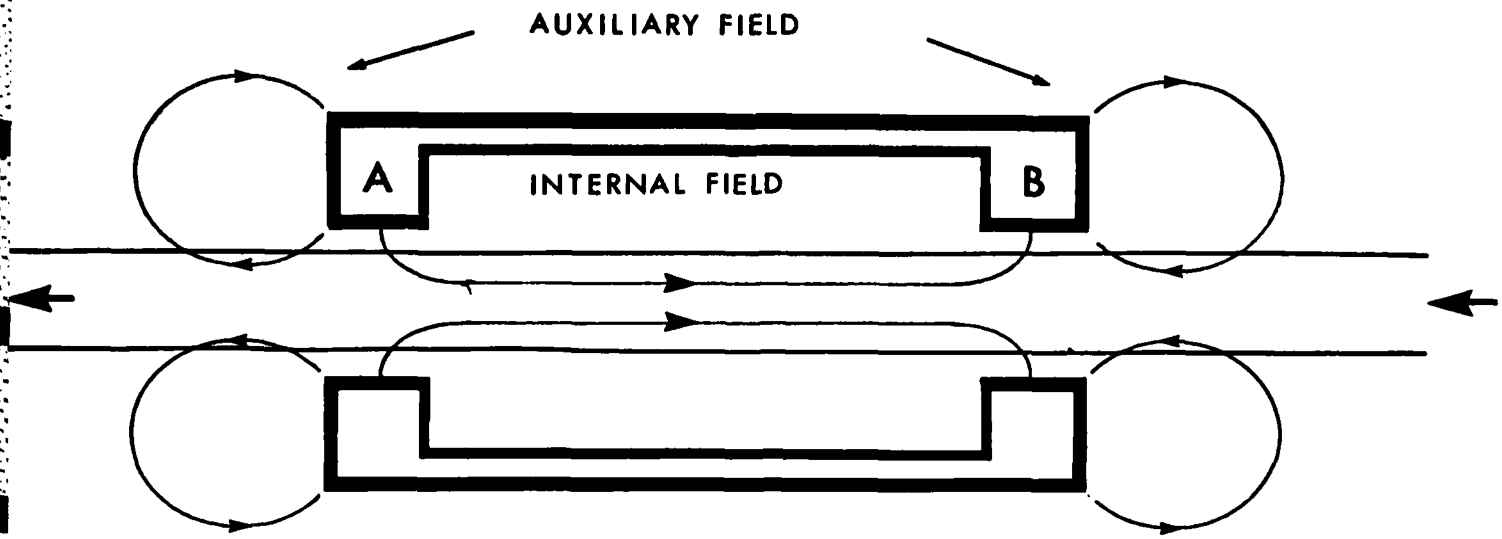


Fig. 4.12 Sensor head Internal and Auxiliary magnetic field

As the rope is moved the part of it leaving A will have remnant magnetism in it. This remnant magnetism will cause Aux. field A to decrease and Internal field A to increase. This change will take place over the first 2-3 feet of rope movement. A previously zeroed LMA chart record will show this increase as in Fig. 4.13.

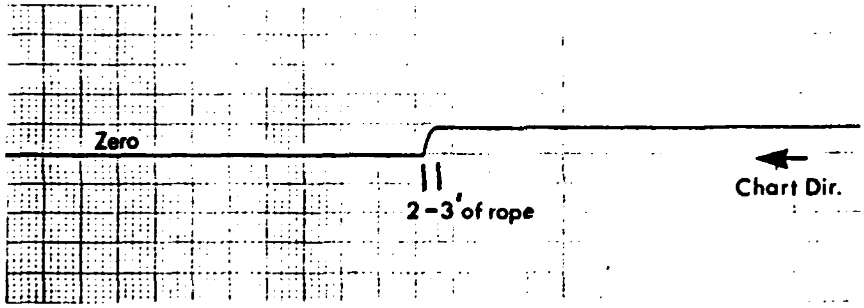


Fig. 4.13 LMA chart record showing zero increase with rope magnetization

This increase in the zero due to magnetization results in a calibration error of the original gain setting by the amount of the increase. ie. a 1% shift in the LMA zero due to the rope being magnetized will mean that the LMA gain setting is off by 1%. This may not be of concern to the user and LMA zero shift due to magnetization on smaller ropes is quite small. Larger ropes (2" plus) may have a shift of 2-3%. With this amount of shift recalibration for the new zero is advisable.

This can be accomplished in the following manner:

i) Set up the instrument as described in section 4.4.3 with the sensor head on good section of the rope.
ii) Advance the rope by 3 feet so that the zero increase due to magnetization is seen on the chart.
iii) Rezero the chart with the LMA Zero Potentiometer and adjust the gain as per the LMA calibration chart.
iv) Start the test.

The LMA zero increase caused by the magnetized rope leaving one end of the machine will also occur as the magnetized rope leaves the other end of the machine.

Once a test is completed the rope which has been run through the machine will be magnetized. If the rope is then run in the opposite direction an LMA zero shift will occur. This is as a result of magnetized rope leaving end B of the machine (see Fig. 4.12) and the Internal magnetic field B increasing. No change occurs in the field A as magnetized material is now entering the head at end A and the zero shift in the LMA due to this field redistributing has already occurred at end A on the previous test. If recalibration of the LMA gain is again desired it can be done by first advancing the rope by 3 feet on this 're-run' and adjusting zero and gain as previously described.

The LMA zero shift due to magnetization has a more important effect on measurements than calibration.

Rope tests are often carried out in two parts due to accessibility of the working length of the rope. Once one section of the rope has been tested care must be taken in testing the rest of the rope as the sensing head will ultimately meet the end of the first test and see the magnetic 'signature' created by the magnetization induced in the rope by the first test. An example is in order to explain this further.

Fig. 4.14 shows the working length of a rope as if it were completely stretched out. The first test was conducted between d1 and d2. To test from 0 to d1 the head should be installed with the <u>same orientation</u> on the rope as the first test. As d1 is approached and passed the sensing head will see a changing magnetic condition from unmagnetized rope entering it to magnetized rope entering it. This will create an LMA chart record as in Fig. 4.15.

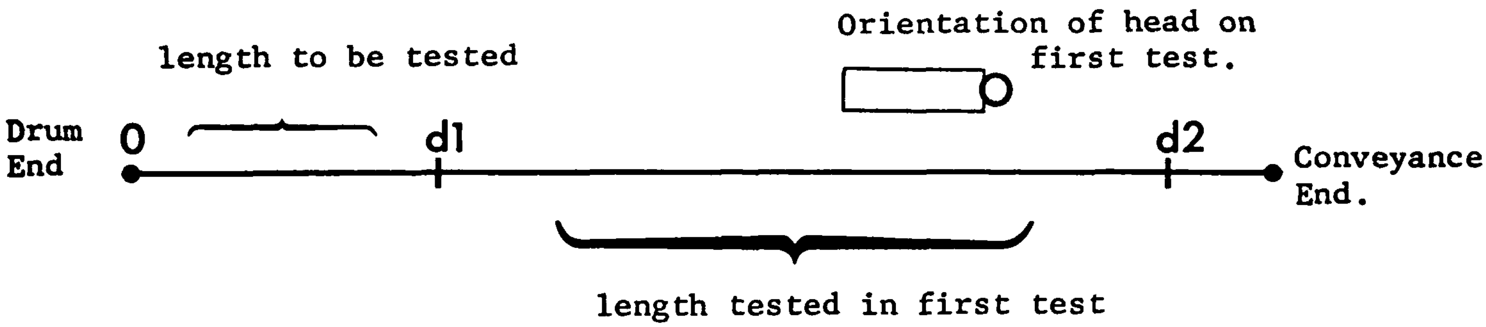


Fig. 4.14 Working length of Rope

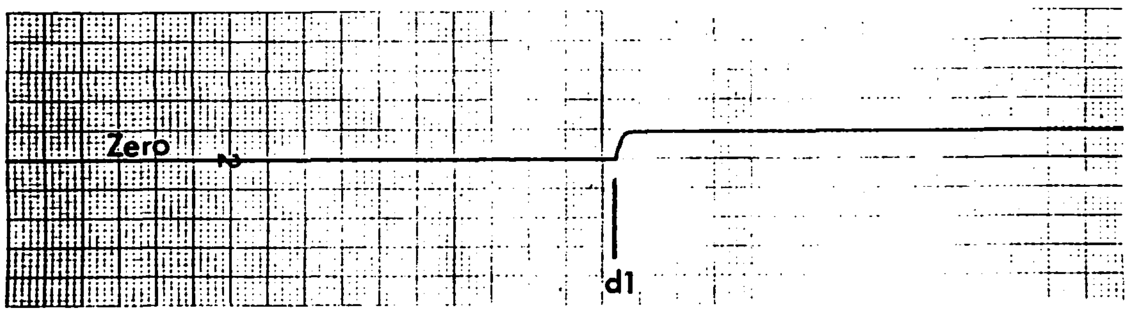


Fig. 4.15 Change in LMA zero when passing the start of the first test.

The danger of this transition is that it may be mistaken as an actual change in the rope condition. If there is confusion as to where d1 is on the charts of the two successive tests, the charts should be overlapped.

For similar reasons running past the end of an earlier rope test (as would occur in retesting past d2) should also be done with care. An example of running over a previous test is shown in Fig.4.15. As can be seen the magnetization ending from the previous test looks very much like an LMA decrease due to wear. In this particular test there is no marked reaction in the LF trace that generally accompanys an LMA decrease of this size. This helps to pinpoint the end of the previous test. As wear increases however, the LF trace will have a larger amplitude and cannot be used effectively to indicate the end of a rope test. Keeping track of where tests start and finish and overlapping charts of adjacent test is a more positive method.

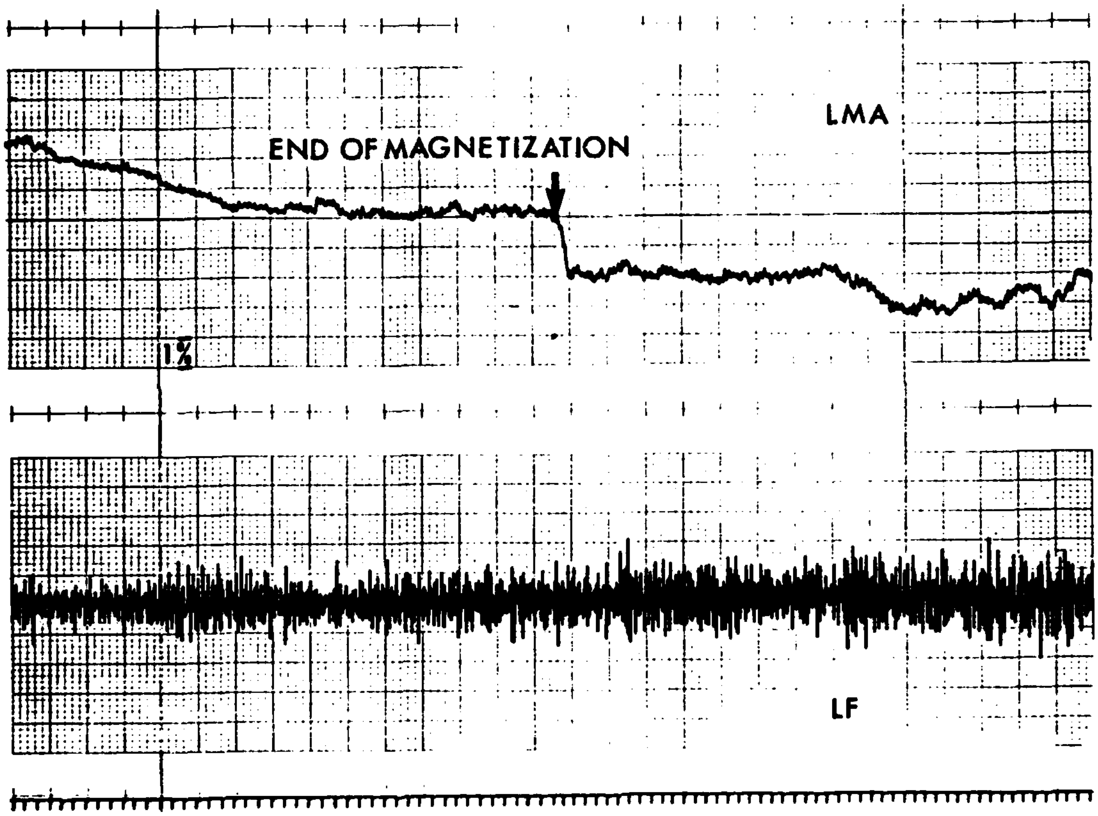


Fig. 4.16 Showing End of Magnetization from previous test. (1 3/4" 6x27 Flattened Strand)

In Fig. 4.9 the LMA zero setting vs. nominal rope weight is shown. This allows the rope weight to be estimated by the zero setting. This graph represents rope weight of 'magnetized' rope with 'magnetized' indicating that the rope on either end of the machine has been magnetized.

4.8 Testing Short Pieces of Rope

Short sample pieces of rope can be tested in the Magnograph. If calibrated LMA readings are required the sample must protrude at least 5 feet on either side of the sensing head. This is required to contain the auxiliary magnetic field. The LF readings are quite insensitive to this 'end effect' and short test pieces may be used if LF readings are required.

4.9 Interpretation and Use of Readings

The readings obtained by the Magnograph should be used to pinpoint areas of a rope which require further visual inspection but should not be considered as a wholesale replacement of visual inspection.

By keeping accurate histories of rope wear, problem areas in the hoisting system or in rope usage will become quite visible. Using this information will allow for more efficient rope use.

4.9.1 Using Readings as a Rope Removal Criterion

The decision to remove a rope from service due to loss of strength is an individual decision for each user. Rope removal is governed by legislation in many countries and users should be aware of how this affects their individual situation.

The metallic area loss (LMA) on a cable is sometimes used as a direct indication of loss of strength. This is sometimes a good estimation or 'starting point' but assumes that all ropes wear and lose strength in the same manner. Even in countries where metallic area loss is used as a direct indication of strength loss considerable variation is found when this is compared to the actual loss of strength. This is due to the fact that many variables contribute to strength loss and metallic area decrease is only one factor. If metallic area loss were the only factor involved it too would show considerable variation in loss of strength depending on where the loss has occurred in the rope.

To achieve some guidelines on the correlation of the readings of the instrument and how strength is being lost in ropes of specific usage it is suggested that actual breaking tests be done on a rope once removed from service. This will allow the user to derive a pattern of strength loss for his specific situation.

5.0 MAINTENANCE AND TROUBLE SHOOTING

The purpose of this section is to provide: an understanding of the operation of the circuitry at a "block" level; a schedule for regular maintenance to ensure serviceability of the equipment for many years to come; and a means of identifying faulty blocks, should a problem arise.

5.1 Block Description

The "FUNCTIONAL BLOCK DIAGRAM" of Fig. 5-1 shows the major divisions in the signal conditioning circuit paths; Sensor Head, Analogue , FM , Digital and Chart Recorder.

5.1.1 Analogue/Sensor Head

The analogue signals, LMA (proportional to cross-sectional area of the rope) and LF (indicative of irregularities in the rope) are derived in the SENSOR HEAD by 8 LMA HALL SENSORS and 4 LF HALL SENSORS. These sensors are excited by DC constant current supplies in the ANALOGUE section of the Control Electronics. The signals are summed, temperature corrected and amplified by two preamplifier boards, one in each half of the SENSOR HEAD, and transmitted up the cable to the Control Electronics.

The LMA signal is summed with LMA ZERO which cancels the 100% rope proportional signal and amplified by means of LMA GAIN to normalize signal changes that they may be expressed in percentage change. This normalized signal is smoothed by a Low Pass Filter and made available to the TAPE RECORDING circuitry, LMA panel METER, and through additional LPF to the CHART RECORDER. At this point the capability of inserting a fixed % OFFSET is offered so that large area changes, up to 25%, may be offset on the chart thus allowing use of optimum sensitivity.

The LF signal is summed with LF ZERO to eliminate any DC levels due to additive DC field components, then Low Pass Filtered to eliminate high frequency transients. (Note: LF ZERO is disabled in the DYNAMIC MODE of operation).

The signal is subsequently amplified by LF GAIN to a level dependant on rope condition, for optimum fault measurement. A band of COMPRESSION ($\pm$) may be selected within which the signal is attenuated by a factor of 10 (eg. background noise). If "0" is selected the signal is unaltered. After this stage the LF signal is made available to the TAPE RECORDING circuitry, the LF panel METER and the CHART RECORDER.

5.1.2 FM

The LMA and LF data can be recorded on magnetic tape for future processing or playback. The FM section consists of voltage to frequency converters for the LF and LMA. These converters produce frequencies above and below their centre frequency of 3KHz in proportion to the signal inputs. A third converter produces one of two frequencies to correspond to its digital 0 or 1 input. This Frequency Shift Keying (FSK) is used to code the Yard or meter marks from the Digital Section.

These signals are recorded at a fixed amplitude on tape and upon playback are decoded and reconstructed by two frequency to voltage converters and a Phase Locked Loop FSK demodulator.

A digital panel indicator allows approximate relocation of any point on a recorded cassette by counting in response to spindle rotation.

5.1.3 Digital/Sensor Head

The tachometer located in the rope guide roller on the Sensor Head, with a fixed rotation to length ratio produces two square waves with a + or - 90° phase relationship. The signals are transmitted up the cable to the Control Electronics. The Digital section sharpens these pulse trains and decodes their phase relationship to indicate one direction of travel or the other. These pulses are counted and a mark for each yard or meter of rope travel is produced. The polarity of the mark is determined by the rope direction.

These marks, whether in real time or decoded from taped data are delivered to an event marker in the Chart Recorder and are also counted to generate a combined 50 and 100 mark indicator which is fed to a second event marker in the Chart Recorder.

The yard/meter marks are counted and indicated on the panel display "MEASURED LENGTH".

A voltage proportional to the speed of the rope is also derived from these marks. It is used to drive a panel display of "ROPE SPEED" and to control the speed of the paper chart recorder in proportion to the speed of the rope. This feature requires that the rope travel at a speed greater than a preset minimum and thus it is enabled by a motion sensor.

5.1.4 Chart Recorder

A two channel paper chart recorder is used to provide hard copy of the data measured by the system.

The LMA and LF signals are delivered to the channel sensitivity controls and attenuated for optimum results.

The YD/M marks and the 50/100 marks are isolated electrically by means of a photo coupler the outputs of which drive the two event marker pens.

The speed of the chart may be controlled either by the internal TIME BASE or by the speed of the rope as selected by the front panel PROP DRIVE switch.

5.2 Maintenance

Very little maintenance is required but adherence to a "clean-up" routine will further reduce the risk of failures.

5.2.1 Chart Recorder

After each day of use of the Chart Recorder any accumulated dust or dirt should be wiped off with a soft cloth. If used under very dusty conditions it may be necessary to remove the works from the cabinet and using low pressure compressed air,blow the dust from the equipment. Removal of the four bottom mounting screws is the only dissassembly required.

Paper wipers and rubbing alcohol should be used to remove any spilled ink from metal work.

Maintenance to the pen and ink supply, paper supply and chart or pen drive mechanisms should be done at regular intervals as specified by the manufacturer's manual (supplied herewith #15-806325-00).

5.2.2 Control

After each day of use of the Control any accumulated dust or dirt should be wiped off with a soft cloth or paper wipes and rubbing alcohol. If used under very dusty conditions it may be necessary to remove the works from the cabinet and using low pressure compressed air, blow the dust from the equipment. Removal of the four bottom mounting screws is the only dissassembly required.

Maintenance of the tape recorder heads and drive system should be performed at regular intervals according to the manufacturer's manual included herewith. (#78-20EM-1A2)

The internal battery in the control should not be left inactive for periods exceeding three months. Every 90 days while in storage for periods of greater duration, the control should be operated by internal battery until the minimum voltage is reached, then allowed to charge for 24 hours. This will ensure long battery life and consistent discharge capacity.

5.2.3 Cables

The cables for interconnection of the components of the system contain multiple pairs of shielded conductors and should not be subjected to great compressive forces. Regular inspections should be made to ensure the integrity of the outer jacket and repairs made with self-vulcanizing silicone rubber tape as required.

After each use of the system the cable should be wiped clean of any grease or oil using a soft cloth dampened with varsol or mineral spirits, then wiped again with rubbing alcohol. This will ensure long life of the P.V.C. outer jacket.

Caution: Do not use solvents such as acetone or MEK as this will dissolve the material in the jacket.

5.2.4 Sensor Head

This component of the system is subjected to the worst abuse in regular service. It must be cleaned often using mineral spirits or varsol to remove the large amounts of grease and oil that accumulate on it.

When cleaning remove the plastic guides and metal inserts and wash them separately in a tray of cleaner using a small short bristled brush.

When cleaning the rest of the body particular attention should be paid to the roller assemblies to ensure they turn freely and are not restricted from good contact with the rope by accumulations of grease or dirt.

Caution: Great care must be taken to prevent damage to wires or connectors or the ingress of foreign matter into either the connectors or the electronics area of the head.

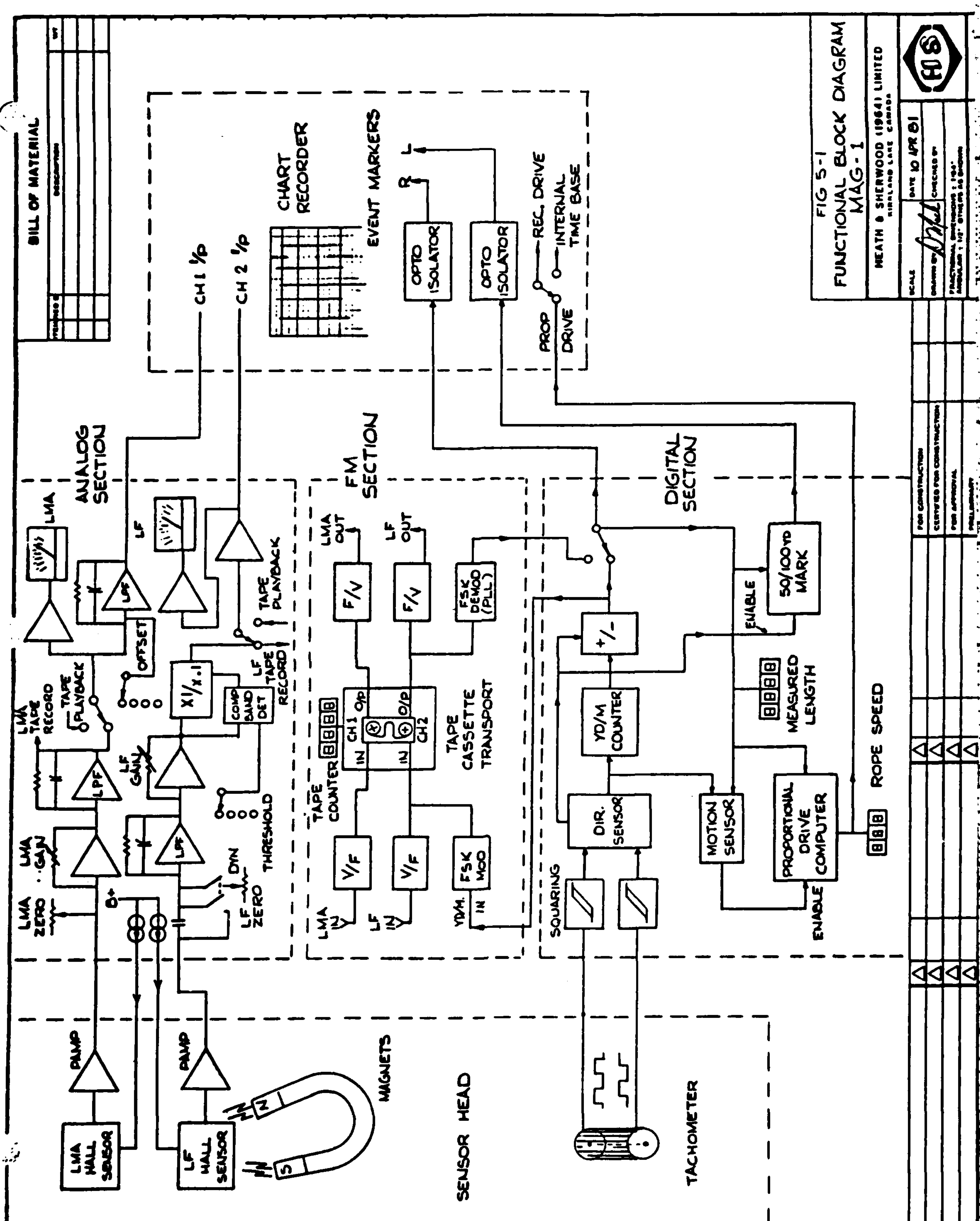
5.3 Trouble Shooting

The following section is intended to aid in the isolation of faulty blocks in the event that a problem should arise.

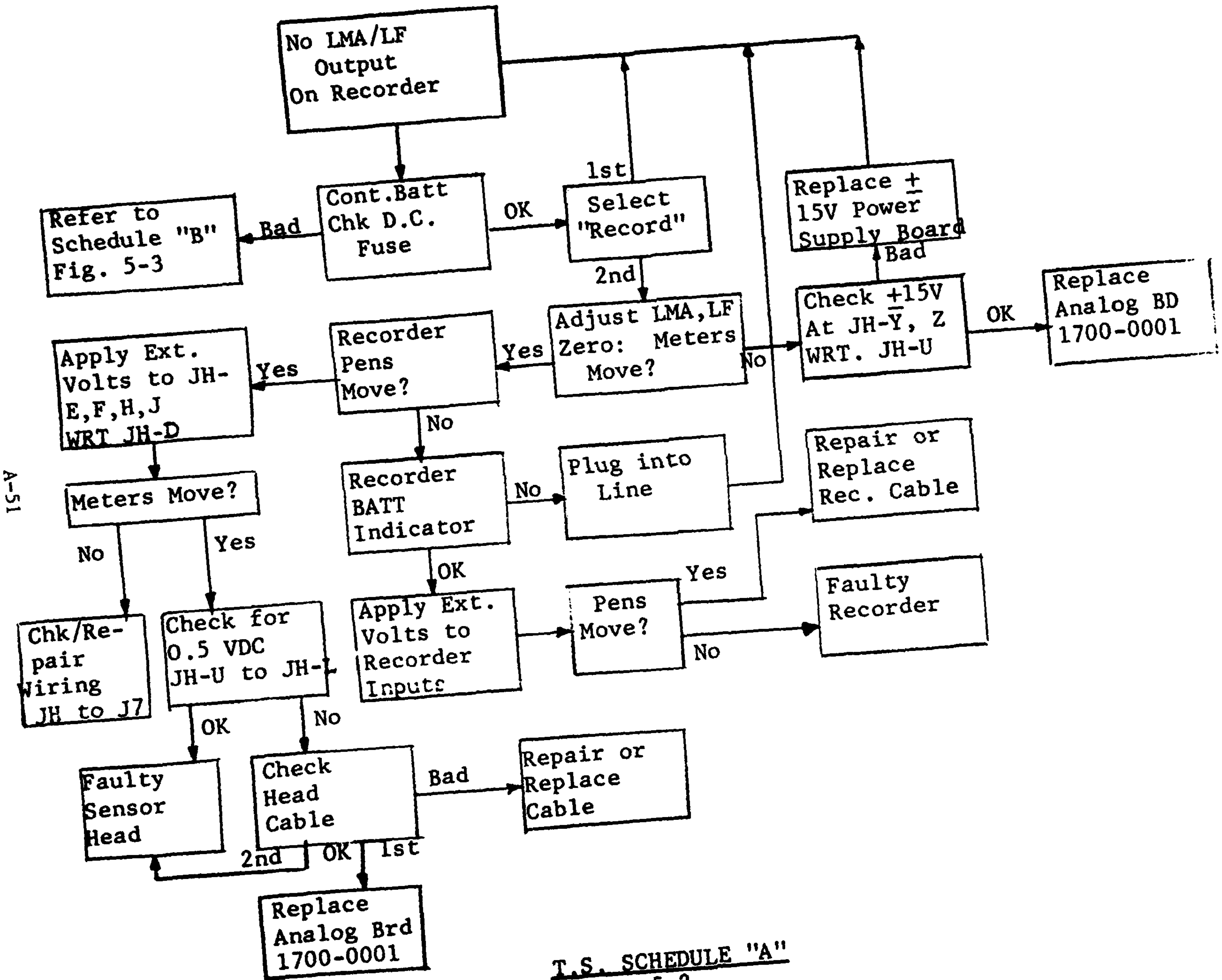
Although these schedules are kept at a "block" level and not "component" level, they should be performed only by those familiar with and qualified to operate various pieces of test equipment such as oscilloscopes, digital voltmeters, soldering irons and other electronic test equipment as may be required.

Reference to the following schematic drawings will be necessary for full understanding in most cases.

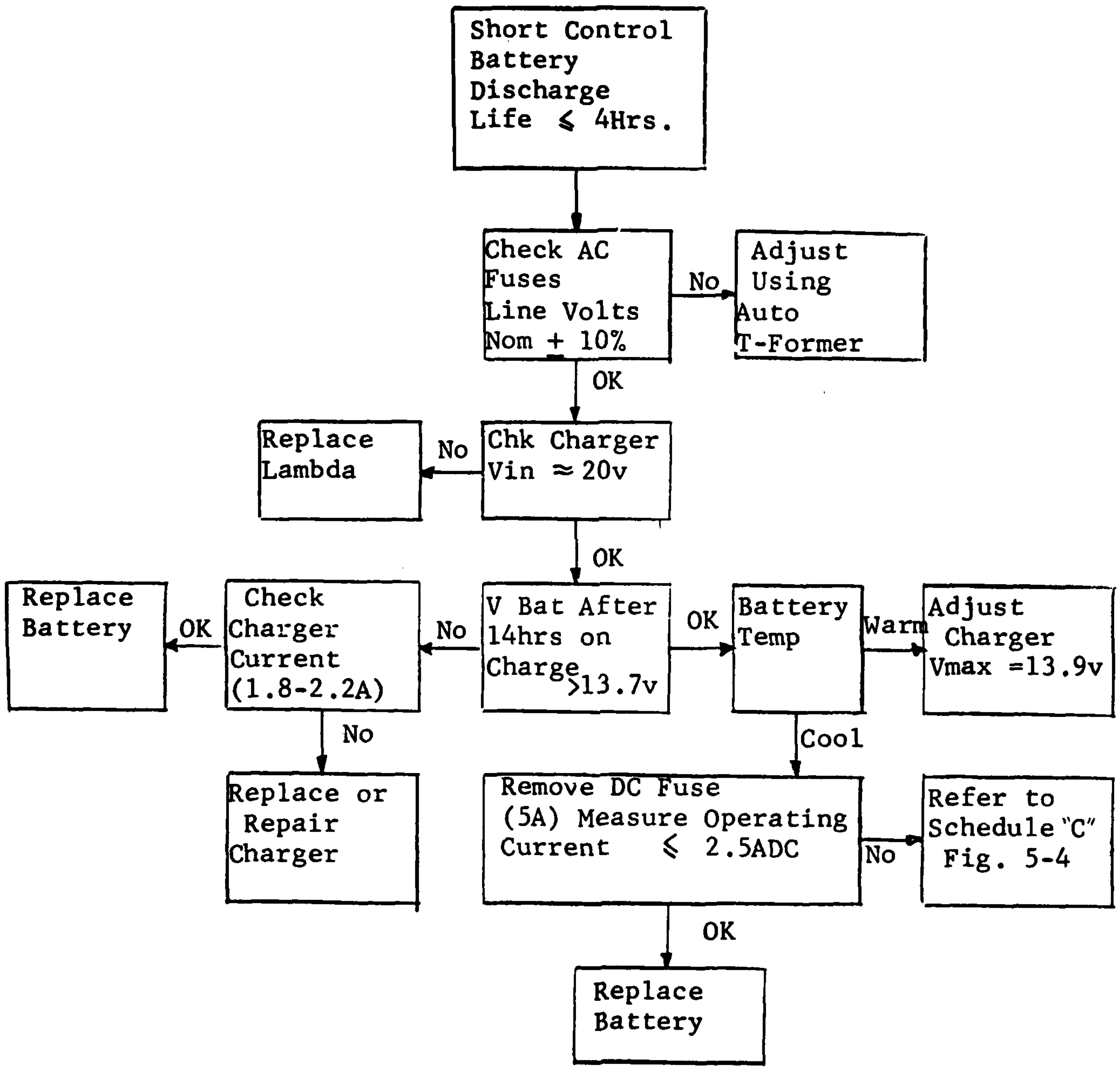
D 7001-0001	MAG-1 Control
C 7001-0002	MAG-1 Recorder
C 7001-0007	MAG-1 Sensor Head
D 6000-0001	MAG-1 Sensor Head Cable
B 6000-0002	MAG-1 Recorder Cable



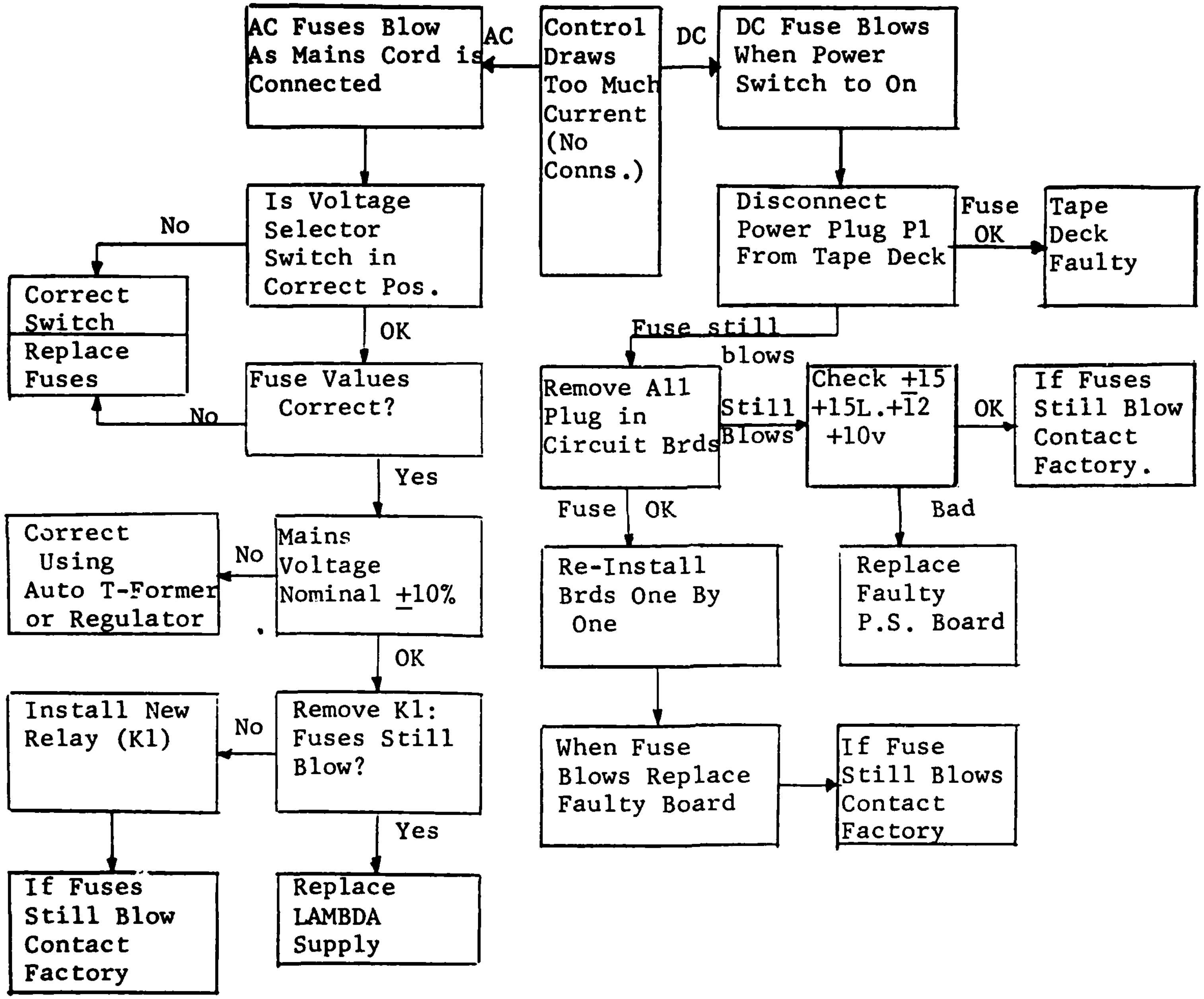
BILL OF MATERIAL
FIG 5-1
FUNCTIONAL BLOCK DIAGRAM
MAG-1
HEATH & SHERWOOD (1964) LIMITED
DATE 10 APR 81
ANALOG SECTION
FM SECTION
DIGITAL SECTION
SENSOR HEAD
TACHOMETER
MAGNETS
CHART RECORDER
EVENT MARKERS
CH 1 I/P
CH 2 I/P
OPTO ISOLATOR
OPTO ISOLATOR
R
L
PROP
DRIVE
REC. DRIVE
INTERNAL TIME BASE
LMA HALL SENSOR
LF HALL SENSOR
PAMP
PAMP
LMA ZERO
LMA GAIN
LF ZERO
DYN
B+
LPF
LF GAIN
THRESHOLD
LMA TAPE RECORD
TAPE PLAYBACK
OFFSET
X1/X.1
COMP BAND DET
LF TAPE RECORD
TAPE PLAYBACK
LMA
LF
LMA IN
LF IN
YD/M. IN
V/F
V/F
FSK MOD
TAPE COUNTER
CH1
CH2
IN
O/P
TAPE CASSETTE TRANSPORT
F/V
F/V
FSK DEMOD (PLL)
LMA OUT
LF OUT
SQUARING
DIR. SENSOR
YD/M COUNTER
+/-
MOTION SENSOR
PROPORTIONAL DRIVE COMPUTER
ENABLE
ENABLE
50/100YD MARK
MEASURED LENGTH
ROPE SPEED



T.S. SCHEDULE "A"
Fig. 5-2

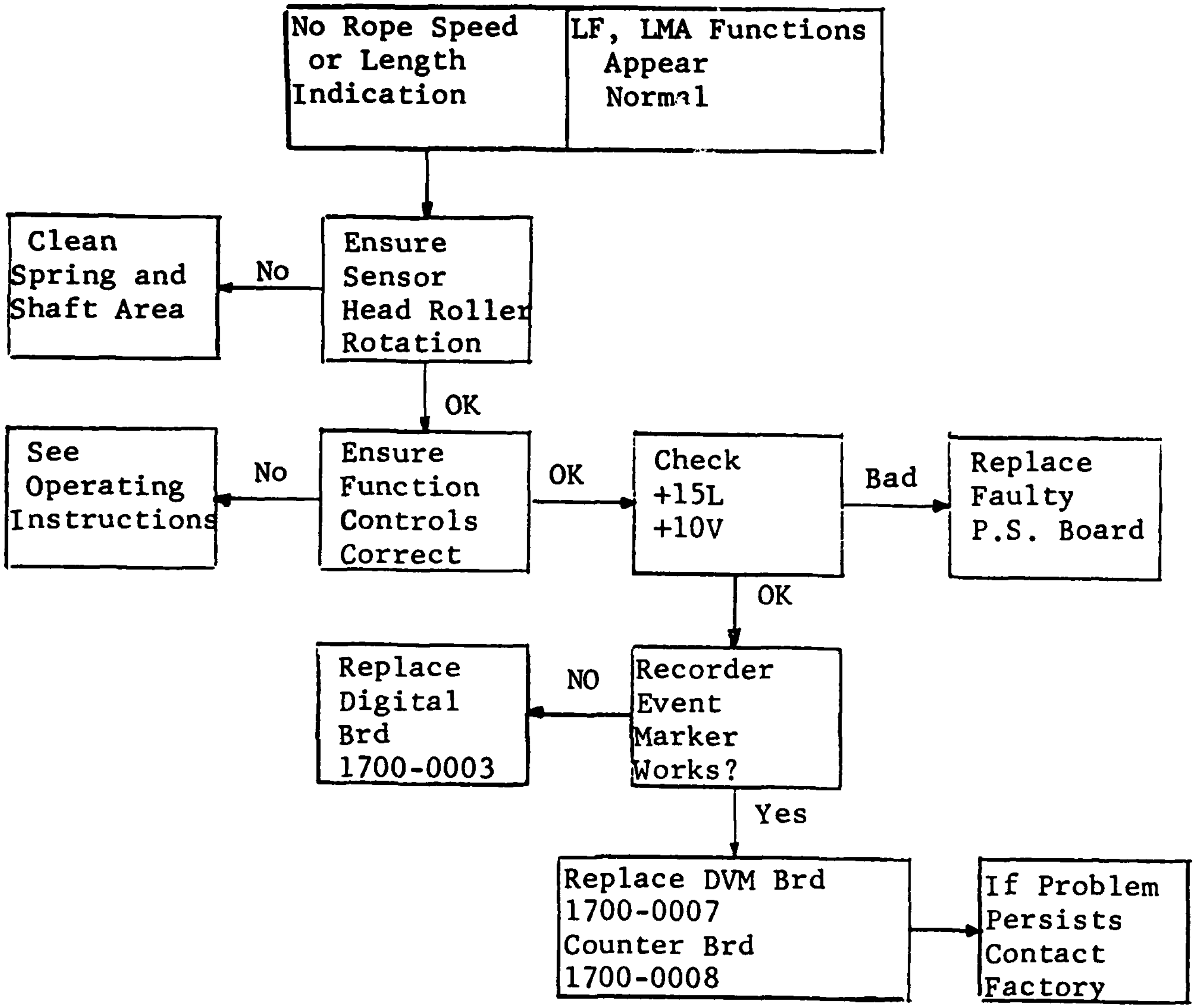


<u>T.S. Schedule "B"</u>
Fig. 5-3



T.S. Schedule "C"

Fig. 5-4



T.S. Schedule "D"
Fig. 5-5

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ARMY COE Philadelphia Dist. (LIBRARY) Philadelphia, PA
ARMY CORPS OF ENGINEERS Fac Engr Supp Agency, Ft. Belvoir, VA; Seattle Dist. Library, Seattle WA
ARMY CRREL A. Kovacs, Hanover NH; Constr. Engr Res Branch, (Aamot); Library, Hanover NH
ARMY CRREL R.A. Eaton
ARMY DARCOM Code DRCMM-CS Alexandria VA
ARMY ENG DIV HNDED-CS, Huntsville AL; HNDED-FD, Huntsville, AL
ARMY ENG WATERWAYS EXP STA Library, Vicksburg MS
ARMY ENGR DIST. Library, Portland OR
ARMY MAT SYS ANALYSIS ACT Code DRXSY-CM (M Ogorzalek) Aberdeen Proving Grnd MD
ARMY MATERIALS & MECHANICS RESEARCH CENTER Dr. Lenoe, Watertown MA
ARMY MOBIL EQUIP R&D COM DRDME-GS Fuel Tech Br, Ft Belvoir, VA; DRDME-MR (J. Sargent) Ft. Belvoir VA
ARMY MTMC Trans Engr Agency MTT-CE, Newport News, VA
ARMY TRANSPORTATION SCHOOL Code ATSPO CD-TE Fort Eustis, VA
ARMY TRNG & DOCTRINE CMD Code ATCD-SL Fort Monroe, VA
ARMY-DEPOT SYS COMMAND DRSDS-AI Chambersburg, PA
BUREAU OF RECLAMATION Code 1512 (C. Selander) Denver CO
CINCLANT CIV ENGR SUPP PLANS OFFR NORFOLK, VA
CINCPAC Fac Engrng Div (J44) Makalapa, HI
CNAVRES Code 13 (Dir. Facilities) New Orleans, LA
CNM Code 03462, Washington DC; Code 043 Washington DC; Code MAT-O8E, Washington, DC; NMAT - 044, Washington DC
CNO Code NOP-964, Washington DC; Code OP 323, Washington DC; Code OP 405, Washington DC; Code OP 405, Washington, DC; Code OP 414, Washington DC; Code OP 97 Washington DC; Code OP 97 Washington, DC· Code OP 987 Washington DC; Code OP323 Washington DC; Code OPNAV 09B24 (H); Code OPNAV 22, Wash DC; Code OPNAV 23, Wash DC; OP-098, Washington, DC; OP-23 (Capt J.H. Howland) Washinton, DC; OP-411F, Wash DC; OP987J, Washington, DC
COMCBPAC Operations Off, Makalapa HI
COMDEVGRUONE CMDR San Diego, CA
COMFAIRWESTPAC Security Offr, Misawa Japan
COMFLEACT, OKINAWA PWD - Engr Div, Sasebo, Japan; PWO, Kadena, Okinawa; PWO, Sasebo, Japan
COMNAVAIRLANT NUC Wpns Sec Offr Norfolk, VA
COMNAVBEACHPHIBREFTRAGRU ONE San Diego CA
COMNAVSURFLANT Norfolk, VA
COMOCEANSYSPAC SCE, Pearl Harbor HI
COMSUBDEVGRUONE Operations Offr, San Diego, CA
NAVSURFPAC Code N-4, Coronado
COMOPTEVFOR CMDR, Norfolk, VA; Code 705, San Diego, CA
DEFENSE INTELLIGENCE AGENCY DB-4C1 Washington DC
DEFFUELSUPPCEN DFSC-OWE (Term Engrng) Alexandria, VA; DFSC-OWE, Alexandria VA
DNA STTL, Washington DC
DTNSRDC Anna Lab (Code 1175) Annapolis MD; Anna Lab (Code 119) Annapolis MD; Anna Lab (Code 1568) Annapolis MD; Anna Lab, Code 2724 (D Bloomquist) Annapolis, MD; Anna Lab, Code 4121 (R A Rivers) Annapolis, MD
DTNSRDC Code 172 (M. Krenzke), Bethesda MD
DTNSRDC Code 284 (A. Rufolo), Annapolis MD
DTNSRDC Code 4111 (R. Gierich), Bethesda MD; Code 42, Bethesda MD
DTNSRDC Code 522 (Library), Annapolis MD
FLTCOMBATTRACENLANT PWO, Virginia Bch VA
FMFLANT CEC Offr, Norfolk VA
FMFPAC CG(FEO) Camp Smith, HI

GSA Assist Comm Des & Cnst (FAIA) D R Dibner Washington, DC ; Fed. Sup. Serv. (FMBP), Washington DC
HCU ONE CO, Bishops Point, HI
KWAJALEIN MISRAN BMDSC-RKL-C
MARINE CORPS BASE 1st For Serv Supp Gru (CSS-5) Camp Pendleton CA; Code 406, Camp Lejeune, NC; M & R Division, Camp Lejeune NC; Maint Off Camp Pendleton, CA; PWO Camp Lejeune NC; PWO, Camp S. D. Butler, Kawasaki Japan
MARINE CORPS HQS Code LFF-2, Washington DC
MCAS CO, Kaneohe Bay HI; Code S4, Quantico VA; Facs Maint Dept - Operations Div, Cherry Point; PWD Utilities Div, Iwakuni, Japan; PWD, Dir. Maint. Control Div., Iwakuni Japan; PWO, Iwakuni, Japan; SCE, Futema Japan
MCDEC M&L Div Quantico VA
MCRD PWO, San Diego Ca
MILITARY SEALIFT COMMAND Washington DC
NAF PWD - Engr Div, Atsugi, Japan; PWO, Atsugi Japan
NALF OINC, San Diego, CA
NARF Code 100, Cherry Point, NC; Code 640, Pensacola FL; Equipment Engineering Division (Code 61000), Pensacola, FL
NAS AUW Officers, Brunswick, ME; CO, Guantanamo Bay Cuba; Code 114, Alameda CA; Code 183 (Fac. Plan BR MGR); Code 18700, Brunswick ME; Code 18U (ENS P.J. Hickey), Corpus Christi TX; Code 6234 (G. Trask), Point Mugu CA; Code 70, Atlanta, Marietta GA; Code 8E, Patuxent Riv., MD; Dir of Engrng, PWD, Corpus Christi, TX; Dir. Maint. Control Div., Key West FL; Dir. Util. Div., Bermuda; Lakehurst, NJ; Lead. Chief. Petty Offr. PW/Self Help Div, Beeville TX; OIC, CBU 417, Oak Harbor WA; PW (J. Maguire), Corpus Christi TX; PWD - Engr Div Dir, Millington, TN; PWD - Engr Div, Gtmo, Cuba; PWD Maint. Cont. Dir., Fallon NV; PWD, Code 1821H (Pfankuch) Miramar, SD CA; PWD, Maintenance Control Dir., Bermuda; PWD, Willow Grove PA; PWO Chase Field Beeville, TX; PWO Key West FL; PWO Lakehurst, NJ; PWO Sigonella Sicily; PWO, Cubi Point, R.P.; PWO, Kingsville TX; PWO, Millington TN; PWO, Miramar, San Diego CA; PWO,, Moffett Field CA; SCE Norfolk, VA; SCE, Barbers Point HI
NASDC-WDC T. Fry, Manassas VA
NATL BUREAU OF STANDARDS B-348 BR (Dr. Campbell), Washington DC; Kovacs, Washington, D.C.; R Chung Washington, DC
NAVACT PWO, London UK
NAVACTDET PWO, Holy Lock UK
NAVAIRDEVCEN Code 813, Warminster PA
NAVAIRPROPTESTCEN CO, Trenton, NJ
NAVAIRTESTCEN PATUXENT RIVER PWD (F. McGrath), Patuxent Riv.,MD
NAVAVIONICFAC PW Div Indianapolis, IN; PWD Deputy Dir. D/701, Indianapolis, IN
NAVAVNWPNSFAC Wpns Offr, St. Mawgan, England
NAVCHAPGRU CO Williamsburg VA
NAVCOASTSYSCEN CO, Panama City FL; Code 423 Panama City, FL; Code 715 (J Quirk) Panama City, FL; Code 715 (J. Mittleman) Panama City, FL; Code 719, Panama City, FL; Code 772 (C B Koesy) Panama City FL; PWO Panama City, FL
NAVCOMMAREAMSTRSTA Code W-60, Elec Engr, Wahiawa, HI; Maint Control Div., Wahiawa, HI; PWO, Norfolk VA; SCF Unit 1 Naples Italy; SCE, Wahiawa HI
NAVCOMMSTA CO. San Miguel, R.P.; Code 401 Nea Makri, Greece; PWD - Maint Control Div, Diego Garcia Is.; PWO, Exmouth, Australia; PWO, Fort Amador Panama Canal
NAVCONSTRACEN Curriculum/Instr. Stds Offr, Gulfport MS
NAVEDTRAPRODEVCEN Technical Library, Pensacola, FL
NAVENVIRHLTHCEN CO, NAVSTA Norfolk, VA
NAVEODTECHCEN Code 605, Indian Head MD
NAVFAC PWO, Centerville Bch, Ferndale CA; PWO, Point Sur, Big Sur CA; SCE
NAVFACENGCOM Code 043 Alexandria, VA; Code 0451 (P W Brewer) Alexandria, Va; Code 0453 (D. Potter) Alexandria, VA; Code 0453C, Alexandria, VA; Code 0454B Alexandria, Va; Code 046; Code 0461D (V M Spaulding) Alexandria, VA; Code 04A1 Alexandria, VA; Code 04B3 Alexandria, VA; Code 051A Alexandria, VA; Code 06, Alexandria VA; Code 100 Alexandria, VA; Code 1002B (J. Leimanis) Alexandria, VA; ROICC Code 495 Portsmouth VA
NAVFACENGCOM - CHES DIV. Code 403 Washington DC; Code 405 Wash. DC; Code 407 (D Scheesele) Washington, DC; Code FPO-1C Washington DC; Code FPO-1E, Wash. DC; Contracts, ROICC, Annapolis MD; FPO-1 Washington, DC; FPO-1EA5 Washington DC; FPO-1P/1P3 Washington, DC
NAVFACENGCOM - LANT DIV. Code 403, Norfolk, VA; Code 405 Civil Engr BR Norfolk VA; Eur. BR Deputy Dir, Naples Italy
NAVFACENGCOM - NORTH DIV. CO; Code 04 Philadelphia, PA; Code 09P Philadelphia PA; Code 111 Philadelphia, PA; Code 405 Philadelphia, PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV. Code 2011 Pearl Harbor, HI; Code 402, RDT&E, Pearl Harbor HI
NAVFACENGCOM - SOUTH DIV. Code 405 Charleston, SC; Code 411 Soil Mech & Paving BR Charleston, SC; ROICC (LCDR R. Moeller), Contracts, Corpus Christi TX

NAVFACENGCOM - WEST DIV. 102; AROICC, Contracts, Twentynine Palms CA; Contracts, AROICC, Lemoore CA; O9P/20 San Bruno, CA
NAVFACENGCOM CONTRACT AROICC MCAS El Toro; AROICC, NAVSTA Brooklyn, NY; AROICC, Quantico, VA; Colts Neck, NJ; Dir, Eng. Div., Exmouth, Australia; Eng Div dir, Southwest Pac, Manila, PI; NAS, Jacksonville, FL; OICC, Southwest Pac, Manila, PI; ROICC AF Guam; ROICC, Diego Garcia Island; ROICC, Pacific, San Bruno CA; ROICC-OICC-SPA, Norfolk, VA
NAVMAG PWD - Engr Div, Guam; SCE, Guam; SCE, Subic Bay, R.P.
NAVOCEANO Code 3432 (J. DePalma), Bay St. Louis MS; Library Bay St. Louis, MS
NAVOCEANSYSCEN Code 4473 Bayside Library, San Diego, CA; Code 4473B (Tech Lib) San Diego, CA; Code 52 (H. Talkington) San Diego CA; Code 5214 (H. Wheeler), San Diego CA; Code 5221 (R.Jones) San Diego Ca; Code 5311 (Bachman) San Diego, CA; Code 6700, San Diego, CA
NAVORDMISTESTFAC PWD - Engr Dir, White Sands, NM
NAVORDSTA PWO, Louisville KY
NAVPETOFF Code 30, Alexandria VA
NAVPGSCOL E. Thornton, Monterey CA
NAVPHIBASE CO, ACB 2 Norfolk, VA; COMNAVBEACHGRU TWO Norfolk VA; Code S3T, Norfolk VA; Dir. Amphib. Warfare Brd Staff, Norfolk, VA; Harbor Clearance Unit Two, Little Creek, VA; OICC/ROICC, Norfolk, VA; SCE Coronado, SD,CA
NAVRADRECFAC PWO, Kami Seya Japan
NAVREGMEDCEN Code 3041, Memphis, Millington TN; PWO Newport RI; PWO Portsmouth, VA
NAVREGMEDCEN PWO, Okinawa, Japan
NAVREGMEDCEN SCE San Diego, CA; SCE, Guam; SCE, Oakland CA
NAVREGMEDCEN SCE, Yokosuka, Japan
NAVSCOLCECOFF C35 Port Hueneme, CA; CO, Code C44A Port Hueneme, CA
NAVSCSCOL PWO, Athens, GA
NAVSCSOL PWO, Athens GA
NAVSEASYSCOM Code 05E1, Wash, DC; Code OOC-D, Washington, DC; Code PMS 395 A 3, Washington, DC; Code PMS 395 A2, Washington, DC; Code SEA OOC Washington, DC; PMS-395 A1, Washington, DC; PMS395-A3, Washington, DC; SEA 04E (L Kess) Washington, DC; SEA-5433, Washington, DC; SEA05E1, Washington, D.C.
NAVSEC Code 6156D, Washington, DC; Code 6157D, Washington, DC
NAVSECGRUACT Facil. Off., Galeta Is. Panama Canal; PWO, Adak AK; PWO, Edzell Scotland; PWO, Puerto Rico; PWO, Torri Sta, Okinawa; Security Offr, Winter Harbor ME
NAVSECSTA PWD - Engr Div, Wash., DC
NAVSHIPREPFAC Library, Guam; SCE Subic Bay
NAVSHIPYD Bremerton, WA (Carr Inlet Acoustic Range); Code 134, Pearl Harbor, HI; Code 202.4, Long Beach CA; Code 202.5 (Library) Puget Sound, Bremerton WA; Code 280, Mare Is., Vallejo, CA; Code 380, Portsmouth, VA; Code 382.3, Pearl Harbor, HI; Code 400, Puget Sound; Code 410, Mare Is., Vallejo CA; Code 440, Norfolk; Commander, Philadelphia, PA; L.D. Vivian; Library, Portsmouth NH; PWD (Code 450-HD) Portsmouth, VA; PWD (Code 457-HD) Shop 07, Portsmouth, VA; PWO, Mare Is.; PWO, Puget Sound; SCE, Pearl Harbor HI; Tech Library, Vallejo, CA
NAVSTA CO Roosevelt Roads P.R. Puerto Rico; CO, Brooklyn NY; Code 4, 12 Marine Corps Dist, Treasure Is., San Francisco CA; Dir Engr Div, PWD, Mayport FL; Dir Mech Engr 37WC93 Norfolk, VA; Engr. Dir., Rota Spain; Long Beach, CA; Maint. Cont. Div., Guantanamo Bay Cuba; Maint. Div. Dir/Code 531, Rodman Panama Canal; PWD (LTJG.P.M. Motolenich), Puerto Rico; PWO, Guantanamo Bay Cuba; PWO, Keflavik Iceland; PWO, Mayport FL; ROICC Rota Spain; SCE, Guam; SCE, Pearl Harbor HI; SCE, Subic Bay, R.P.; Security Offr, San Francisco, CA; Utilities Engr Off. Rota Spain
NAVSUBASE Code 23 (Slowey) Bremerton, WA; SCE, Pearl Harbor HI
NAVSUPPACT PWO Naples Italy
NAVSUPPFAC PWD - Maint. Control Div, Thurmont, MD
NAVSURFWPNCEN PWO, White Oak, Silver Spring, MD
NAVTECHTRACEN SCE, Pensacola FL
NAVWPNCEN Code 2636 China Lake; Code 266, China Lake, CA; PWO (Code 266) China Lake, CA; ROICC (Code 702), China Lake CA
NAVWPNEVALFAC Sec Offr, Kirtland AFB, NM
NAVWPNSTA (Clebak) Colts Neck, NJ; Code 092, Colts Neck NJ; Maint. Control Dir., Yorktown VA
NAVWPNSTA PW Office Yorktown, VA
NAVWPNSTA PWD - Supr Gen Engr, Seal Beach, CA; PWO, Charleston, SC
NCBU 405 OIC, San Diego, CA
NCTC Const. Elec. School, Port Hueneme, CA
NCBC Code 10 Davisville, RI; Code 155, Port Hueneme CA; Code 1571, Port Hueneme, CA; Code 400, Gulfport MS; Code 430 (PW Engrng) Gulfport, MS; PWO, Davisville RI; PWO, Gulfport, MS
NCBU 411 OIC, Norfolk VA
NCR 20, Code R70; 20, Commander; 30th Det, OIC, Diego Garcia I
NMCB 74, CO; Forty, CO; THREE, Operations Off.
NOAA (Dr. T. Mc Guinness) Rockville, MD; Library Rockville, MD

NORDA Code 440 (Ocean Rsch Off) Bay St. Louis MS; Code 500, (Ocean Prog Off-Ferer) Bay St. Louis, MS
NRL Code 5800 Washington, DC; Code 8441 (R.A. Skop), Washington DC
NROTC J.W. Stephenson, UC, Berkeley, CA
NSC Code 54.1 Norfolk, VA
NTC OICC, CBU-401, Great Lakes IL
NUSC Code 332, B-80 (J. Wilcox) New London, CT; Code EA123 (R.S. Munn), New London CT; Code SB 331 (Brown), Newport RI; Code TA131 (G. De la Cruz), New London CT
OFFICE SECRETARY OF DEFENSE ASD (MRA&L) Code CSS/CC Washington, DC; OASD (MRA&L) Dir. of Energy, Pentagon, Washington, DC
ONR Central Regional Office, Boston, MA; Code 221, Arlington VA; Code 485 (Silva) Arlington, VA
PHIBCB 1, CO San Diego, CA; 1, CSWC D Wellington, San Diego, CA
PMTC Code 3144, (E. Good) Point Mugu, CA; Code 3331 (S. Opatowsky) Point Mugu, CA; Code 4253-3, Point Mugu, CA; EOD Mobile Unit, Point Mugu, CA
PWC CO, Pearl Harbor HI; Code 105 Oakland, CA; Code 110, Oakland, CA; Code 128, Guam; Code 200, Great Lakes IL; Code 200, Guam; Code 400, Pearl Harbor, HI; Code 420, Oakland, CA; Code 500 Norfolk, VA; Code 505A Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego Ca; Code 700, Great Lakes, IL; Code 700, Norfolk, VA; Code 700, San Diego, CA; Utilities Officer, Guam
SPCC PWO (Code 120) Mechanicsburg PA
SUPANX PWO, Williamsburg VA
TVA Smelser, Knoxville, Tenn.; Solar Group, Arnold, Knoxville, TN
UCT ONE OIC, Norfolk, VA
UCT TWO OIC, Port Hueneme CA
U.S. MERCHANT MARINE ACADEMY Kings Point, NY (Reprint Custodian)
US GEOLOGICAL SURVEY Off. Marine Geology, Piteleki, Reston VA
US NATIONAL MARINE FISHERIES SERVICE Highlands NY (Sandy Hook Lab-Library)
US NAVAL FORCES Korea (ENJ-P&O)
USAF SCHOOL OF AEROSPACE MEDICINE Hyperbaric Medicine Div, Brooks AFB, TX
USCG (G-MP-3/USP/82) Washington Dc; (Smith), Washington, DC; G-EOE-4 (T Dowd), Washington, DC
USCG R&D CENTER CO Groton, CT; D. Motherway, Groton CT; Tech Dir, CT
USDA Forest Products Lab, Madison WI; Forest Products Lab. (R. DeGroot), Madison WI; Forest Service, Bowers, Atlanta, GA; Forest Service, San Dimas, CA
USEUCOM (ECJ4/L-LO), Wright, Stuttgart, GE
USNA Civil Engr Dept (R. Erchyl) Annapolis MD; ENGRNG Div, PWD, Annapolis MD; NAVSYSENGR Dept, Annapolis, MD; PWO Annapolis MD
USS FULTON WPNS Rep. Offr (W-3) New York, NY
WATER & POWER RESOURCES SERVICE (Smoak) Denver, CO
AMERICAN CONCRETE INSTITUTE Detroit MI (Library)
CALIF. DEPT OF NAVIGATION & OCEAN DEV. Sacramento, CA (G. Armstrong)
CALIF. MARITIME ACADEMY Vallejo, CA (Library)
CALIFORNIA INSTITUTE OF TECHNOLOGY Pasadena CA (Keck Ref. Rm)
CALIFORNIA STATE UNIVERSITY (Yen) Long Beach, CA; LONG BEACH, CA (CHELAPATI)
CLARKSON COLL OF TECH G. Batson, Potsdam NY
COLORADO STATE UNIV., FOOTHILL CAMPUS Fort Collins (Nelson)
CORNELL UNIVERSITY Ithaca NY (Serials Dept, Engr Lib.); Ithaca, NY (Civil & Environ. Engr)
DAMES & MOORE LIBRARY LOS ANGELES, CA
DUKE UNIV MEDICAL CENTER B. Muga, Durham NC; DURHAM, NC (VESIC)
UNIVERSITY OF DELAWARE (Dr. S. Dexter) Lewes, DE
FLORIDA ATLANTIC UNIVERSITY Boca Raton FL (W. Hartt); Boca Raton, FL (McAllister)
GEORGIA INSTITUTE OF TECHNOLOGY (LT R. Johnson) Atlanta, GA
HARVARD UNIV. Dept. of Architecture, Dr. Kim, Cambridge, MA
INSTITUTE OF MARINE SCIENCES Morehead City NC (Director)
IOWA STATE UNIVERSITY Ames IA (CE Dept, Handy)
WOODS HOLE OCEANOGRAPHIC INST. Woods Hole MA (Winget)
LEHIGH UNIVERSITY BETHLEHEM, PA (MARINE GEOTECHNICAL LAB., RICHARDS); Bethlehem PA (Fritz Engr. Lab No. 13, Beedle)
MAINE MARITIME ACADEMY CASTINE, ME (LIBRARY)
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MIT Cambridge, MA (Harleman)
NATL ACADEMY OF ENG. ALEXANDRIA, VA (SEARLE, JR.)
NATURAL ENERGY LAB Library, Honolulu, HI
NEW MEXICO SOLAR ENERGY INST. Dr. Zwibel Las Cruces NM
NY CITY COMMUNITY COLLEGE BROOKLYN, NY (LIBRARY)
OREGON STATE UNIVERSITY (CE Dept Grace) Corvallis, OR; CORVALLIS, OR (CE DEPT, BELL); CORVALLIS, OR (CE DEPT, HICKS); Corvalis OR (School of Oceanography)
PENNSYLVANIA STATE UNIVERSITY STATE COLLEGE, PA (SNYDER)
PORTLAND STATE UNIVERSITY H. Migliore Portland, OR

PURDUE UNIVERSITY Lafayette IN (Leonards); Lafayette, IN (Altschaeffl); Lafayette, IN (CE Engr. Lib)
SAN DIEGO STATE UNIV. 1. Noorany San Diego, CA
SCRIPPS INSTITUTE OF OCEANOGRAPHY LA JOLLA, CA (ADAMS); San Diego, CA (Marina Phy. Lab. Spiess)
SEATTLE U Prof Schwaegler Seattle WA
SOUTHWEST RSCH INST King, San Antonio, TX; R. DeHart, San Antonio TX
STATE UNIV. OF NEW YORK Buffalo, NY; Fort Schuyler, NY (Longobardi)
TEXAS A&M UNIVERSITY College Station TX (CE Dept. Herbich); W.B. Ledbetter College Station, TX
TEXAS TECH UNIVERSITY Dept of IE (Prof. Ayoub), Lubbock TX
UNIVERSITY OF ALASKA Marine Science Inst. College, AK
UNIVERSITY OF CALIFORNIA A-031 (Storms) La Jolla, CA; BERKELEY, CA (CE DEPT, GERWICK); BERKELEY, CA (CE DEPT, MITCHELL); Berkeley CA (Dept of Naval Arch.); Berkeley CA (E. Pearson); DAVIS, CA (CE DEPT, TAYLOR)
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UNIVERSITY OF PENNSYLVANIA P. McCleary Dept of Architecture Philadelphia, PA; PHILADELPHIA, PA (SCHOOL OF ENGR & APPLIED SCIENCE, ROLL)
UNIVERSITY OF RHODE ISLAND Narragansett RI (Pell Marine Sci. Lib.)
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UNIVERSITY OF WASHINGTON Seattle WA (M. Sherif); Dept of Civil Engr (Dr. Mattock), Seattle WA; SEATTLE, WA (MERCHANT); SEATTLE, WA (OCEAN ENG RSCH LAB, GRAY); SEATTLE, WA (PACIFIC MARINE ENVIRON. LAB., HALPERN); Seattle WA (E. Linger); Seattle, WA Transportation, Construction & Geom. Div
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WESTINGHOUSE ELECTRIC CORP. Annapolis MD (Oceanic Div Lib, Bryan); Library, Pittsburgh PA
WISS, JANNEY, ELSTNER, & ASSOC Northbrook, IL (D.W. Pfeifer)
WM CLAPP LABS - BATTELLE DUXBURY, MA (LIBRARY)
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AL SMOOTS Los Angeles, CA
ANTON TEDESKO Bronxville NY
BRAHTZ La Jolla, CA
BULLOCK La Canada
DOBROWOLSKI, J.A. Altadena, CA
ERVIN, DOUG Belmont, CA
GERWICK, BEN C. JR San Francisco, CA
LAFKIN Seattle, WA
LAYTON Redmond, WA
CAPT MURPHY Sunnyvale, CA
PAULI Silver Spring, MD
BROWN & CALDWELL Saunders, E.M./Oakland, CA
SMITH Gulfport, MS
T.W. MERMEL Washington DC
WM TALBOT Orange CA